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# E L E M E N T S

OF THE

## *ART of DYING.*

CONTAINING

THE THEORY OF DYING IN GENERAL,

AS FAR AS IT RESPECTS THE PROPERTIES OF COLOURING  
SUBSTANCES.

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Translated from the FRENCH of

*M. BERTHOLLET,*

MEMBER OF THE ACADEMY OF SCIENCES OF PARIS,

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## ADVERTISEMENT.

THE Publishers were preparing to lay before the Public, a complete translation of M. Berthollet's whole works, by an able hand: the translation was considerably advanced, and some progress had been made in the printing, when the unexpected appearance of another translation of the same book in London, rendered it eligible for them to desist from the undertaking, as the London market was thus pre-occupied.

Sensible, however, that the translation which they were about to publish may well bear a comparison with that which has appeared, and believing that the first part, which they printed, may, even separately, prove of considerable utility to Students of Chemistry, and Practitioners in the Art of Dying; they, upon these grounds, presume to offer it to the Public.

The general properties of colouring substances, and of those other bodies which are employed to fix colours upon the matters to which they are applied; the action  
of

of air and light upon colours ; the influence of the nitric and oxigenated muriatic acids in colouring animal substances ; the nature of galls and of astringents in general ; with the characters of wool, silk, and flax as subjects for the Art of Dying, are the topics treated of in the part of M. Berthollet's book now published in an English dress.

# E L E M E N T S

OF THE ART OF

## D Y I N G.

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### PART FIRST.

OF DYING IN GENERAL.

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#### SECTION FIRST.

OF THE GENERAL PROPERTIES OF COLOURING SUBSTANCES.

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#### CHAP. I.

*Of colouring Particles, and their Affinities.*

THE physical theory of colours is foreign to the object of this work. Before considering the characters of colouring substances, I shall only indulge myself in a few reflections on the manner in which the particles of bodies absorb certain rays of light, transmit or reflect others, and in that way produce colour.

Newton has demonstrated, in his Optics, that transparent bodies, according to the difference of their thickness and density, reflect rays of one colour, and transmit those of another.

M. Laval \* has endeavoured to extend the proofs of the Newtonian theory to all the colours of bodies permanently coloured, and he has collected a great number of experiments, in order to prove that the difference of colour in these bodies is exactly in proportion to the density of their constituent parts.

The application of the beautiful experiments upon colours reflected by thin and transparent plates to bodies permanently coloured, is founded upon analogies which did not escape the genius of Newton; but we cannot as yet say how far it is possible to obtain direct proofs of this theory, or to deduce from it any thing certain with regard to particular colours. For,

1<sup>st</sup>, The same colours are successively produced by plates, the thickness of which increase in a progressive order; so that we cannot, from the colour produced by a transparent plate, whatever its kind may be, determine its precise thickness.

2<sup>d</sup>, The tenuity of the particles of bodies and their density are two elements, which, according to Newton, combine in the transparent plates to produce colour; and a plate of water, air, or glass, ought to be of different degrees of thickness, in order to reflect the same colour. But we have no method of determining either the tenuity or the density of the particles of bodies. The specific gravity is not sufficient for this purpose, for small particles, with very numerous pores, may give the same specific gravity as more extensive pores, and a smaller number of large particles.

Thus,

\* Recherches expérimentales de changements de couleurs, dans les corps opaques et naturellement colorés.



Thus, when M. Laval asserts that the order of colours which metals give to glass is in proportion to their specific gravity, he refutes himself by the facts he adduces; for he observes, that we can make glass yellow by means of iron, lead, or silver, the specific gravities of which are very different. Mercury combined with a small quantity of oxygen is black, but by combining it with a greater quantity it becomes red. Iron passes through almost every variety of colour, according to the quantity of oxygen with which it is combined; and the changes of specific gravity that result from the different proportions of oxygen are very small, and far less considerable than the differences which exist among the specific gravities of these metals.

The same author alleges that alkalies give a green tinge to many blue vegetable colours, because they increase the density of their particles; and that acids change them to a red, because in dissolving they attenuate them: but alkalies also dissolve the greater part of colouring particles, and render them more miscible with water than they are in their natural state; they must therefore act in a manner analogous to acids: besides, acids dissolve blue colouring particles without changing their colour: thus the solution of indigo, in the sulphuric acid, retains its blue colour although it be diluted with a great quantity of water; but according to M. Laval's mode of reasoning, the density of the blue particles ought then to undergo a considerable change. In short, many vegetable substances are changed by means of a very weak acid, or a small quantity of an alkali, from a red colour

to a green, without our being able to perceive any of the shades which ought to intervene.

The tenuity and density of the particles are not the only circumstances which ought to be considered ; it is evident, even from the experiments of Newton, that their chemical nature has much influence upon their colours ; for we cannot doubt, that a force which exerts a strong action upon the rays in their refraction, will also affect their reflection.

In comparing the refractive powers of different substances, Newton found that inflammable bodies possessed this power in a much higher degree than substances not inflammable : he deduced from his observations the surprizing conclusion that the diamond must contain much inflammable matter, that water is an intermediate substance, between inflammable and unflammable bodies, and that it is water which affords to vegetables their inflammable principle : truths that, of late only, have been understood, and demonstrated by experiment.

There still remain many interesting observations for those who wish to follow the path of the great Newton, and to compare the refractive power of the different gases and other substances, the constituent principles of which are at present known. Is it hydrogen or carbon which contributes most to the refractive power of inflammable substances ? By attending to the experiments which have been made upon the diamond, we would be inclined to consider it as carbon pure and crystalized ; but in oil of turpentine, which has a considerable refractive power, hydrogen forms the prevailing ingredient.

Many

Many chemical-experiments prove that oxygen also has a considerable affinity with light ; it combines with it without separating any of its rays ; and resumes an elastic state by this combination, which it always forms when not prevented by a stronger affinity. From this it happens, that when we expose to the light oxygenated muriatic acid, the oxygen, which is but feebly retained, quits the acid, and assumes the elastic state by becoming saturated with the principle of light : the same disengagement is produced when we expose nitric acid to the rays of the sun, but with greater difficulty, because in this acid the oxygen is more strongly combined. Oxygen is also disengaged in the same manner from some oxids, or metallic calces.

When a principle enters in a large proportion into any substance, it generally renders itself evident by the properties which it communicates, notwithstanding the changes they may undergo. Thus oxygen, in combining with metals, communicates to them the property of acting more forcibly upon the rays of light ; but the action which they then exert is unequal with regard to rays of different kinds, until the affinity of the oxygen is sufficiently weakened by heat, so that all the rays may combine with it, and render it elastic. It is on this account that metallic oxids change their colours by slight variations in the proportions of oxygen. In this view the oxid of manganese presents a very remarkable phenomenon. When it is saturated with oxygen, it appears black if its particles are collected together ; but if they are extended or dispersed as in glass, into which they are made to enter only in a certain proportion, it gives a red colour,

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which



which proves that the apparent black is owing to the red particles being brought into cloſer contact. If we deprive it of a great part of its oxygen, either by carbon or by any other ſubſtance which can ſeparate this principle, the glaſs becomes perfectly tranſparent, and loſes its colour; but we can re-produce the colour by means of nitre, or any other ſubſtance that can reſtore to manganese the oxygen which it had loſt. It is in this manner we explain its uſe in the art of making glaſs; it deſtroys the carbonaceous ſubſtances which might alter the purity of the glaſs, and by this means it loſes the property of giving it a colour, provided it be added only in the proper proportion.

In metallic oxids, and in many mineral ſubſtances, all the parts are equally coloured; but it is not ſo with vegetable or animal ſubſtances; in them, colour is generally owing to particles which are mixed or combined with the parts that form theſe ſubſtances; and vegetables ſometimes contain different colouring particles at different periods of their exiſtence, and in different parts.

The colouring molecules of vegetable and animal ſubſtances are almoſt the only ones uſed in dying; but they are often modified by admixtures. In this treatiſe they will be diſtinguiſhed by the name of Colouring particles.

Theſe colouring particles do not exhibit, in their compoſition, the ſimplicity of mineral ſubſtances, and their colours are not affected in the ſame manner by oxygen. We ſhall examine, in one of the following chapters, the manner in which this principle acts upon and decompoſes them.

Some

Some chemists have considered iron as the cause of all vegetable and animal colours; and M. Becker has employed, to support this opinion, arguments taken from the property that a metal, so generally diffused, has, of assuming a great variety of colours, in the state of an oxid, in solutions, and in vitrifications\*.

Iron indeed appears to be contained in all vegetable and animal substances, but in an extremely small quantity. The oak, which is one of those vegetable substances that ought to give the greatest residuum, affords by combustion only  $\frac{1}{200}$  of its weight in ashes, and these ashes do not contain  $\frac{1}{200}$  of iron. Can we explain, by so small a quantity, the rich and shining colours with which vegetables are enamelled? Is there any true relation between the readiness with which some of these colours are changed, by acids, by alkalies, and by air, and that constant succession of colours which iron assumes, according to its state of oxidation?

I know that the opinion I combat may be supported by the authority of Bergman, who has endeavoured to prove that indigo owes its colour to the iron which it contains†; but I shall only remark, that it is easy to prove that this great chemist has been deceived with regard to this point. By means of the prussiate of alkali, he obtained from the ashes of an ounce of indigo from 30 to 32 grains of Prussian blue, and he calculates the iron it contained at 18 or

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\* Specimen sistens experimenta circa mutationem colorum quorundam vegetabilium à corporibus salibus, cum corollariis; auctore J. F. Adolpho Becker, 1779.

† Analyse chimique de l'indigo. Mem. des Sav. étr. tom. IX.

20 grains ; but, in some other places, he proves that the iron contained in any substance does not form more than a fifth part of the Prussian blue that we obtain from its solution, and he has every where else employed this calculation, which is very exact. He ought then to have calculated the iron that he obtained from an ounce of indigo at no more than six grains ; but in the experiments which follow, he proves that the greatest part of this iron may be dissolved by the muriatic acid, without any alteration of the colouring particles, so that the greatest part of the metal does not enter into their composition. It follows clearly from this, that the colouring particles of this substance contain a quantity of iron so small, as to affect its colour only in a very inconsiderable degree. It appears to me also, that it is upon very weak grounds that physiologists have concluded, from the experiments of Menghini, that iron is the immediate cause of the colour of the blood.

The methods of chemical analysis which we possess, do not enable us to determine with sufficient precision the composition of the colouring particles, in order to know from what principles they derive their properties, and it can be shown that a very different composition may give rise to a colour of the same kind. The particles of indigo differ much from those which give a blue colour to many flowers. We have a great number of yellow substances, differing widely in their properties, and yet affording colours nearly similar in appearance.

There are some colours which are simple ; there are others which are owing to a mixture of these colours,  
and



and which are consequently compound. Newton has given a general rule for producing any colour whatever, by means of the other prismatic colours. Le Blon has shown, that we can procure every colour which the art of painting requires, by a mixture of red, of blue, and of yellow \*. Dufay found, that we can obtain the same effect in dying, and on this account he concludes that there are only three primitive colours in nature, from which all the rest are derived. This opinion has been adopted by many philosophers, but it is easy to prove that it is without foundation.

There is this difference between simple colours and colours formed by the union of different rays, that the former seen through the prism retain their simplicity, while the latter are decomposed. But the green produced by the rays of this colour suffers no decomposition by the prism; it possesses then the character of a simple and primitive colour, but that which is compound is separated into yellow and blue. Although the green that we obtain in dying is owing to a mixture of yellow and blue, yet we ought not to consider all greens as a combination of these two kinds of colouring particles; thus the green oxid of copper cannot owe its colour to particles of a different nature: and the green colour of plants is undoubtedly produced by a homogeneous substance, as well as the greater part of the shades which exist in nature.

I say, that the greater part of vegetable colours appear to me to be owing to a homogeneous substance, but this substance may produce green, for example,  
by

\* *L'Harmonie du coloris dans la peinture réduite en pratique.*

by the reflection of a green ray, or by that of yellow and blue rays; and there are several colours, which are necessarily produced by the reflection of different kinds of rays. If the green colour of plants be owing to two substances, one of which is yellow, and the other blue; it appears surprising that we cannot separate them, or at least change their proportions by some solvent; however, there are substances which contain colouring particles of different kinds, such as madder, as we shall afterwards see in the second part.

The green, which I take as an example of a real compound colour produced by dying, makes it evident, that the colouring particles cover only a part of the surface of the stuff, although it appears of a full and uniform colour; for, after the stuff has been dyed blue, the yellow parts are fixed on it, and produce the green; and what proves that it is upon the parts of the stuff, and not upon those of the indigo that they are chiefly fixed, is, that although we begin the dying with a yellow, if we employ a yellow that is not very fixed, it may be destroyed by the air, and especially by chemical agents, while the blue remains almost without any alteration.

From this, it appears that it is only necessary that rays of different colours should be brought together, in order to give us an idea of a simple colour. Indeed we can produce a uniform colour by the careful mixture of wool of different colours, and in painting we obtain simple shades by the mixture of different ingredients which do not combine together.

The

The colouring particles form different combinations, and they are applied to wool, to silk, to thread, and to cotton, either alone, or previously combined with other substances. The art of dying consists in employing the affinities of the colouring particles in order to extract, dissolve, and afterwards apply, and fix them on the substances to be dyed.

Some have attempted to distinguish colouring particles into extractive and resinous; but this division can only give imperfect and false ideas of their properties; for there are colouring particles, which, not being soluble in water, might be considered as resinous, were they not equally insoluble in alcohol. Such are the red colouring part of the carthamus, (bastard saffron), which is dissolved only by means of an alkali, and indigo; which is neither soluble in water nor in alcohol, but which is readily dissolved in the sulphuric acid, and by means of certain processes is rendered soluble in alkalies.

The colouring particles which are dissolved in water cannot be compared to the mucilaginous and extractive parts of vegetables; since the property which these substances possess, of dissolving in water, affords no idea of the properties which are essential to them; such as their relations with the chemical agents which are used in dying, with air, with light, and with vegetable and animal substances.

There is another error, hurtful to the progress of true theory; that of attempting to explain the properties of colouring substances by the mucilaginous, resinous, earthy, saline, and oily particles, which are supposed to enter into their composition in the man-



ner that Mr Poerner has chiefly attempted. An error similar to the absurd explanations that have often been given of the action of medicines. (Vid. Mater. Med. Cartheuf.)

Thus we see, that in explaining the cause of colours, and the nature of colouring particles, authors have fallen into two mistakes; one, that of endeavouring to explain the action which the particles of colouring substances exert upon the rays of light, by their density and thickness, without having any method to determine, or without any regard to the affinity depending on their chemical composition; the other, that of comparing on some feeble analogies, the colouring particles with mucilages and resins, and endeavouring to explain their properties from the parts which are supposed to enter into their composition; while their colouring properties ought rather to be determined by direct experiment, than explained by any imaginary composition. It was little consonant to true theory, which is only the result of observation, to attribute to laws purely mechanical the adhesion of colouring particles to the substances which we dye; the action of *mordants*, and the difference of the colours of the true and false dye. Hellot, to whom we are indebted for the best work extant on dying, has deceived himself completely on this subject; his theoretical ideas have often influenced his observations and the principles which he has established, as any one may be convinced of by reading his work. We may judge of his theory by the following passage: "I believe we may lay it down  
" as a general principle in the art of which I treat, that  
" the whole invisible mechanism of dying consists in  
" dilating

“ dilating the pores of the body to be dyed, in depositing in them the particles of a foreign substance, and retaining them there by a kind of cement, which neither water nor rain, nor the rays of the sun can alter. In choosing colouring particles of such tenuity, that they may be retained, properly wedged in the pores of the substance opened by the heat of boiling water, then contracted by cold, and afterwards coated with a kind of varnish, that the salts employed in preparing the stuffs had left in the pores; from this it follows, that the pores of the fibres of wool, which we have formed, or mean to form into stuffs, ought to be cleansed, enlarged, varnished, and then contracted; so that the colouring particle may be retained like a diamond in the beasel of a ring\*.”

We have reason to be surprized, that Macquer, who was one of the first who entertained just notions with regard to chemical affinities, should have been seduced by the ideas of Hellot†. “ It would be easy, in this place,” says he, “ to explain the manner in which *mordants* act in dying, and to develop the cause of the true and false dye; but these objects have been treated so well by M. Hellot, that I need only refer the reader to his work.”

However, M. Dufay had already perceived that the colouring particles were disposed according to their different natures to form a stronger or weaker adhesion to the filaments which receive them: he observes, very properly, that, without this disposition,  
the

\* L'Art de la teinture des laines. p. 42.

† L'Art de la teinture en soie, avant-propos, p. 8.

the stuffs ought only to assume the colour of the dying vat, and to divide equally the colouring particles with it; whereas the liquor of the vat becomes sometimes as clear as water, and yields all the colouring particles to the stuff; which seems (says he) to prove that the ingredients adhere less strongly to the water than to the particles of the wool. He adds, that we can account in the same manner for several other appearances; but that such an explanation is still unsatisfactory, and that he would abandon it without reluctance, if a more probable one were proposed.

Bergman seems to have been the first who referred the phenomena of dying completely to chemical principles\*: having dyed wool and silk in a solution of indigo in the sulphuric acid much diluted with water, he explains, in the following manner, the effects that he observed in this operation; he attributes them to the precipitation occasioned by the greater affinity subsisting between the wool and silk, and the blue particles, than between the same particles and the acidulated water: he remarks, that this affinity of the wool is sufficiently strong to deprive the liquor entirely of its colouring particles, but that the weaker affinity of the silk can only diminish the proportion of these particles in the vat; and he has made it appear, that upon these different affinities depend both the durability of the colour and the intensity which it assumes.

This is the proper method of considering the phenomena

\* Analyse de l'indigo, Mem. des Sav. etre. T. IX. et dans les notes sur le traité de Scheffer.



mena of dying ; they are true chemical phenomena, which ought to be analysed like all those that depend upon the action which bodies exert in consequence of their peculiar nature.

Colouring particles have chemical properties, which distinguish them from all other substances ; they have affinities which are peculiar to themselves ; in consequence of these affinities, they combine with acids, alkalies, metallic oxids, with some earths, and principally with alumine: they frequently precipitate the oxids and alumine from the acids which hold them in solution ; in other circumstances, they combine with salts, and form with them supra-compounds which unite to wool, to silk, to cotton, and to thread. In general, they form with these last substances, by means of alumine, or of a metallic oxid, a much more intimate combination than without this admixture.

The difference of the affinity of the colouring particles with wool, silk, and cotton, is sometimes such, that they refuse to combine with one of these substances, while they combine very readily with another ; thus, cotton is not affected in the vat which dyes wool of a scarlet colour. Dufay caused a piece of stuff to be made, of which the warp was wool and the woof cotton : in order to be certain that the wool and cotton received exactly the same preparation, he made the piece pass through the hands of the fuller ; but the wool took on the colour of scarlet, and the cotton remained white. It is this difference of affinity that obliges us to vary our preparations and processes, according to the nature of the substance that we wish to dye of any particular colour.

These

These considerations ought to fix the plan we are to follow in explaining the art of dying.

It is undoubtedly proper to attempt to ascertain what the constituent parts of colouring particles are; for although this analysis alone cannot as yet lead us to extensive conclusions, we shall see, however, that we are already able to determine in what certain changes produced in these particles by different agents consist.

It is of the utmost consequence to determine the relations of the colouring substance, *1<sup>st</sup>*, With the substances that may be employed as solvents; *2<sup>dly</sup>*, With those which can by their combination modify their colour, increase their brightness, and assist in fixing their union with the substances dyed; *3<sup>dly</sup>*, With the different agents which can alter their colour, and principally with air and light.

It must not be forgotten, that the qualities of free colouring particles are changed when they enter into combination with any substance; but if this combination unites with the stuff, it undergoes itself new changes. Thus the properties of the colouring parts of cochineal are modified by its combination with the oxid of tin, and those of the substance which result from this combination are also modified in combining with wool or with silk; so that the knowledge we acquire by examining substances by themselves, can only inform us as to the preparations they may be made to undergo; that which we acquire with regard to the combinations with substances employed to fix or to increase the beauty of colours, may direct as to those processes in dying that ought to be adopted or that  
may

may be attempted ; but it is only direct experiment made with the different substances to be dyed, that can verify our conjectures and bring processes into use.

In this series of observations, we are frequently able to explain the circumstances of an operation which we owe entirely to a blind practice, improved by the trials of many ages ; we separate from it every thing superfluous ; we simplify what is complicated ; and we employ analogy in transferring to one process what has been found useful in another. But there is still a great number of facts which we cannot explain, and which elude all theory : we must then content ourselves with detailing the processes of the art ; not attempting idle explanations, but waiting till experience throw greater light upon the subject.

It follows from the preceding observations, that the changes produced by acids and alkalies in many vegetable colours, and of which chemists make great use in ascertaining the nature of different substances, are owing to the combination which is formed between the colouring particles and the acids or alkalies. We may compare the compounds that are formed to neutral salts, which possess properties different from those of their component parts, but in which one of the component parts may become superabundant, so that the properties shall prevail. We observe this state of combination between the colouring particles of cochineal and the acidulated tartar of potash, or cream of tartar ; by evaporating slowly a solution of this salt in a decoction of cochineal, crystals are formed which preserve a beautiful ruby colour, much deeper and

more lively than that of the liquor in which they are formed.

There are acids, particularly the nitric acid, which, after being united with colouring particles, alter the colour they at first produced, render it yellow, and destroy it. They act then by means of one of their component parts, the oxygen, in a manner that will be explained when we come to treat of the action of air, and of the oxygenated muriatic acid upon colouring particles.

The blue are not the only colours that become red by the action of acids, and green by that of alkalies; the greater part of red colours, that of the rose for example, are heightened by acids, and become green by alkalies; and some green colours, such as the green decoction of Burdock, according to the testimony of M. Nöfe, and the green juice of the berries of Buckthorn, according to the observation of M. Becker, become also red by acids.

This property, common to the most ordinary vegetable colours, seems to prove, that there is a strong analogy between the greater part of their colouring particles: and it was not without foundation that Linnæus imagined that the red colour in vegetables was owing to an acid, and was a proof of its existence in them\*; but there are many vegetables which contain

\* The colour of some flowers appears to be naturally modified by a very weak acid without being decidedly red: such is the flower of the violet, the juice of which becomes blue when it is allowed to remain for a time in a vessel of tin; probably because the acid it contained combines with the oxidated part which is found on the surface



tain an acid fully elaborated, without having any red colour.

Colouring particles have their affinities with acids, alkalies, earths, and metallic oxids, which partly constitute their chemical properties, and according to which their colours undergo greater or less changes.

These particles form then with the stuff\* upon which they are fixed, a combination which retains only a part of their primitive properties, in uniting with allum, metallic oxids, and some other substances. They are also modified; but the properties of these last combinations are still the same when united with the stuff. All these changes are similar to what we observe in other chemical combinations. They will afterwards be examined more in detail.

## CHAP. II.

### *Of Mordants.*

**WE** give the name of *Mordant* to substances employed in facilitating or modifying the combination of the colouring particles with the stuffs which are to be dyed.

B 2

*Mordants*

surface of the vessel; such also is the flower of the mallow, which becomes blue by simple drying. These recover their primitive hue from the addition of a very small quantity of acid. Observ. Physico-chym. sur les couleurs. Journ. de Phys. tom. VIII.

\* Throughout this work, the word *stuff* means any thing that is the subject of dying, whatever may be its nature or form.

*Mordants* deserve the greatest attention; it is by their means we vary colours, that we increase their brightness, that we fix and render them more durable.

The analysis of the action of *mordants* is what in a peculiar manner converts dying into a chemical art, and a more extensive knowledge of their effects must contribute much to the perfection of this art.

I shall describe, in the third section, the essential properties of the chemical agents which are chiefly employed as *mordants*: I shall ascertain, in treating of each colouring substance, the effects they produce upon it. In this chapter I shall examine in what the action of the principal *mordants* consists, and endeavour to determine how their affinities intervene between the colouring particles and the stuff, and how they influence the qualities of the colours.

A *mordant* is not always a simple agent; for among the substances of which it is composed, there are sometimes formed new combinations, so that the substances employed do not act directly, but the combinations which result from their mixture.

Sometimes we mix the *mordant* with the colouring particles, at other times we impregnate the stuff with it; in other circumstances we unite these two methods, or we may dye successively with liquors containing different substances, the last of which can act only upon the particles with which the stuff is already impregnated.

As the art of printing calicoes exhibits many processes, in which it is easy to prosecute the effects of *mordants*, I shall take a few examples from it, which will render more intelligible the theory afterwards to be



be explained. The *mordant* applied to cloths that are to receive different degrees of red, is prepared by dissolving in 8lbs. of hot water 3lbs. of alum, and 1 lb. of acetite of lead, or sugar of lead; and we add to it 2 oz. of potash, and afterwards 2 oz. of chalk in powder\*.

The alum is decomposed by the acetite of lead, because the oxid of lead combines with the sulphuric acid, and forms an insoluble salt which is precipitated; the base of the alum or alumine combines at the same time with the acetic acid, by which an acetite of alumine is formed; the chalk and the potash serve to saturate the excess of the acid.

One great advantage that results from the formation of the acetite of the alumine is, that the alumine is retained in it by an affinity much weaker than in alum, so that it parts more readily with its solvent, to combine with the stuff and the colouring particles.

A second advantage is, that the acid liquor from which the alumine is separated acts less powerfully upon the colour when it is the acetic acid, than when it is a stronger acid, such as the sulphuric.

Lastly, the acetite of alumine not possessing the property of crystallizing, the *mordant*, that is thickened by means of starch or gum, before applying it to the mould on which the pattern is engraved, does not become rough and unequal, as it might if it contained alum that would crystallize.

Let us follow the operation which is performed upon a piece of cloth when it is impregnated by the *mer-*

B 3

*dant*

\* We shall be more particular on this head in treating of *madder*.

*dant* in the manner determined by the pattern : it is put into a madder vat ; the whole piece is coloured, but the colour is deeper upon the parts that have received the *mordant*. There the colouring particles are combined with the alumine, and with the cotton ; so that it is this triple combination that is formed, and the acetous acid being disengaged from its base, is left suspended in the vat.

The colouring particles combined with the alumine and the stuff are far less easily affected by external agents than when they are either isolated or united to the stuff without any intermediate substance ; and it is upon this property that the operations are founded to which the cloth is afterwards subjected : after having passed through the madder vat, it is boiled with bran, and exposed upon the bleaching field ; and these operations are alternately repeated, till the base becomes white. The colouring particles, which are not united with the alumine, are altered in their composition, dissolved, and separated ; while those which are combined, resist, and are preserved without alteration ; so that the stamp alone remains coloured.

This destruction of the colouring particles, by exposure on the field, and by boiling with bran, seems to be produced, and ought to be explained in the same manner with that of the colouring particles of thread ; the only difference in the process is, that we employ bran instead of alkalies, because the latter would dissolve a part of the colouring substance which is fixed by the alumine, and would alter its colour ; whereas the bran, having a much less affinity for this substance, acts only upon the colouring particles that have been  
disposed

disposed by the influence of the air, to dissolve more readily.

If, instead of the *mordant* we speak of, we employ a solution of iron, the same phenomena take place; the colouring particles decompose the solution of iron, and form a triple combination with the stuff. But, instead of a red colour, we obtain from the madder different shades of brown, from the lightest even to a black, and by uniting the *mordant* of the alum to that of the iron, we obtain mixt colours, which are partly red, and partly black; such are the *mordoré* or golden, and the *puce* or flea colour.

In short, we procure other colours, by using woad instead of madder; and by means of these two colouring substances, indigo blue, and the two *mordants* of which we have been speaking, we obtain the greater part of the varied shades that we observe on printed cloths.

The substances which enter into the composition of a *mordant* cannot sometimes be decomposed by the force of their own affinities; but the affinity of the stuff for one of the constituent parts occasions a decomposition, and new combinations, and sometimes this effect cannot be produced, or at least completed, without the aid of the affinity of the colouring particles. This appears to be the case with the mixture of alum and tartar, which is the *mordant* chiefly employed in the dying of wool.

I dissolved equal weights of alum and tartar; this last salt acquired by the mixture a greater degree of solubility than natural; but by evaporation, and by a second crystallization, the alum and the tartar separa-



ted, so that they had not been decomposed. I boiled half an ounce of alum with an ounce of wool for an hour; a precipitate was formed, which I washed carefully: this precipitate was chiefly composed of small filaments of wool encrusted with earth. I exposed it to the action of the sulphuric acid, dried it by evaporation, and dissolved the residuum, from which I obtained crystals of alum; it deposited carbonaceous particles. I evaporated the liquor which had been boiled with the wool; I obtained from it a few grains of alum; the remainder did not crystallize. I redissolved it, and precipitated the alumine by an alkali; the precipitate was of a slate colour, it became black upon burning charcoal, and gave out alkaline vapours.

We see from this experiment, that the wool decomposed the alum, that a part of the alumine combined with the filaments which were the most isolated and the most weakly kept together by the force of aggregation; that an animal matter had been dissolved and precipitated by the alkali from the triple combination which was formed.

I made the same trial with half an ounce of alum and two drachms of tartar; in this there was no precipitate formed. I obtained, by evaporation, a small part of the tartar and some crystals of alum of a very irregular figure; the remainder did not crystallize. I diluted it with water, and precipitated it with potash, and I obtained, by evaporation, a salt that burned like tartar.

The wool which had been boiled with the alum, became rough to the touch, but the other preserved its softness; the former assumed with the madder a duller colour,

four, though less deep ; and the latter a colour more full and lively. — 177

I cannot give in detail the explanation of what took place in these experiments, but we see,

1<sup>st</sup>, That the wool had begun to decompose the alum, that it combined with a part of the alumine, and that the part of the alum which retained its alumine had dissolved a small quantity of an animal substance.

2<sup>d</sup>, That the tartar and the alum, which are not mutually decomposed when they act only by their own affinities, may act upon one another when their affinities are altered by those of the wool.

3<sup>d</sup>, The tartar appears to be particularly useful in moderating the too great action of the alum upon the wool, which is somewhat injured by it ; thus no use is made of tartar for the aluming of silk and thread, which have less action upon the alum than wool.

As the decomposition of the alum by the tartar and the wool is only produced by affinities, which lose their equilibrium with difficulty ; and as, of consequence, it can only be performed slowly, we may perceive why it is advantageous to keep for some days in a moist place, the stuff impregnated with alum and tartar, as is commonly advised.

The last result of the aluming, in whatever manner it may have been performed, and whatever the chemical changes may be which have been produced, consists in the combination of the alum with the stuff. This combination is perhaps at first imperfect, having parted with only a portion of the acids ; but it is completed,



completed by boiling the wool with madder, just as we have seen it performed on printed cloths.

An acid and an alkali may, at the same time, be united with the stuff, the colouring substance, and the alumine; for there are colours which are altered by an acid, and restored by an alkali, or by a calcareous earth, which deprives them of their acid, or produces an effect contrary to it. But this supracomposition takes place only with colours which may be considered as fixed, and which are unalterable by acids or alkalies that are not sufficiently strong to destroy their composition.

The affinity of alumine for animal substances is not indicated by doubtful phenomena only, nor invented to serve merely for explanation; it is demonstrated by direct experiments. I have formed this combination by mixing an alkali, saturated with an animal substance, with a solution of alum; a double exchange takes place; the alkali unites with the acid of the alum, while the alumine is precipitated in combination with the animal substance\*.

I have proved, by another experiment, the affinity of the alumine for animal substances. After having mixed a solution of strong glue and a solution of alum, I precipitated the alumine with an alkali; it carried along with it the strong glue with which it had been combined: this combination has the appearance of a semitransparent jelly, and is dried with difficulty†.

We have seen also in the preceding experiments, that the alkali had precipitated the alumine combined with

\* Mém. de l'acad. 1784.

† Ann. de chym. tome IV. p. 155.

with the animal substance, from the uncrySTALLIFABLE residuum of the alum which had been boiled with the wool.

The affinity of alumine for the greater part of colouring substances may also be demonstrated by direct experiment. If we mix a solution of a colouring substance with a solution of alum, a precipitate is sometimes formed ; but if we add to the liquor an alkali which decomposes the alum, and separates the alumine from it, then the colouring particles are precipitated in combination with the alumine, and the liquor remains clear. It is to this combination that we give the name of Lac: we must not, in making this experiment, use too great a quantity of alkali, because the alkali has the property of re-dissolving the greater part of lacs.

No direct experiment has hitherto proved the affinity of alumine for any vegetable substances, except the colouring particles ; it appears to be much weaker than that which it has for animal substances : it is for this reason that the acetite of alumine, as has formerly been observed, is a better *mordant* for cotton and thread than alum, and on this depend the different methods employed to increase the solidity of the colouring particles of the madder in the dying of these substances.

The metallic oxids have such an affinity with some colouring particles, that in order to precipitate themselves in combination with them, they quit the acids by which they are held in solution.

On the other hand, all the metallic oxids have the property of combining with animal substances ; and I have formed these different combinations by mixing an alkali, saturated with animal matter, with metallic solutions

solutions \*. It need not then appear surprising, that metallic oxids may serve to promote the union between the colouring particles and animal substances ; but, besides the affinity of oxids for the colouring particles and animal substances, there are in their acid solutions properties which render them more or less fit to serve as *mordants* : thus oxids that part readily with their acids, such as the oxid of tin, may combine with animal substances without the aid of colouring particles ; it is enough to impregnate the wool or the silk with the solution of tin, although we afterwards wash them carefully, which does not happen with some other metallic solutions.

Some metallic substances bring into their combinations only a white and colourless base, there are others that modify, by the union of their colours, that which is peculiar to the colouring particles ; but in many metallic oxids the colour varies according to the proportion of the oxygen that is fixed in them, and this proportion may readily undergo some changes. On these circumstances, which will be examined in the sequel of this section, depend principally their properties in dying.

The affinity of metallic oxids for substances of a vegetable nature, appears to be much weaker than that which they have for animal substances, and it is even unknown whether they can form true combinations with them. Thus, metallic solutions are not very fit to serve as *mordants* for the colours of cotton and thread. It is necessary, however, to except iron, the

\* Mém. de l'acad. 1784.



the oxid of which combines strongly with vegetable substances, as the spots of mildew, which are produced by a true combination of this oxid, demonstrate.

When the colouring particles have precipitated a metallic oxid from its solvent, the supernatant liquor retains the acid which has been set at liberty; it has generally the power of dissolving a portion of the combination of the colouring substance with the metallic oxid, so that the liquor remains coloured; but sometimes all the colouring particles are precipitated when the proportions are very exact; this precipitation is facilitated and rendered more complete by the presence of the stuff, which acts also by the tendency which it has to unite with the combination of metallic oxids and colouring particles.

The free metallic oxids, when boiled with several colouring substances, have also a very considerable action upon them by which their colour is changed. The oxid of tin in a particular manner increases the brightness and solidity of some colours.

We may compare the combinations of oxids with colouring substances to several other chemical combinations, that are insoluble when the principles which form them exist in the proper proportions; but which may be combined with an excess of one of these principles, and in that way be rendered soluble. Thus, a metallic oxid combined with an excess of colouring matter forms a liquor the colour of which is modified by the oxid; whereas, when the colouring particles are not in excess, the combination is insoluble or nearly



ly so\*. These effects are very evident in the combination of iron with the astringent principle.

Neutral salts, such as nitre, and especially muriate of soda, serve as *mordants*, and to modify colours; it is difficult to determine in what manner they act. I have found that the muriate of soda exists in substance in the precipitates that it forms with some colouring substances; and that these precipitates retain a tolerable degree of solubility. It would appear that a small part of the salt is fixed with the colouring particles and the stuff.

Salts with a calcareous base also modify colours; but as these changes are almost similar to those that a small quantity of quick lime would occasion, it is probable that they are decomposed, and that a small portion of the lime enters into combination with the colouring particles of the stuff.

If we attend to what has already been said, the combinations which are formed by the action of the different re-agents that are employed in the analysis of colouring substances will be easily understood; but it must not be forgotten, that *mordants* and colouring particles exert a mutual action, by which their properties may be altered.

We have already perceived, that by varying the *mordants* we can multiply prodigiously the shades that are obtained from a colouring substance; it is even sufficient to vary the method of applying them. Thus different results are obtained by impregnating the stuff with a *mordant*,

\* Observations sur la combinaison des oxides metalliques avec les parties astringentes & les parties colorantes des vegetaux. (Ann. de chym. tom. I.)

*mordant*, or by mixing the *mordant* in the dying vat, by making use of heat, or by employing desiccation; for we have three reciprocal affinities, that of the colouring particles, that of the stuff, and that of the principles of the *mordant*; and many circumstances can produce variations in the result of each of these affinities, which merit some explanations.

Desiccation favours the combination of the substances which have an affinity with the stuff, and the decompositions that may result from this combination; because the water which holds these substances in solution opposes, by its affinity, the action of the stuff; but the desiccation ought to be slow, that the substances may not separate before their reciprocal affinities have produced their effect. From this it may be understood in what manner the repeated desiccations act which are employed in some processes.

The greater or less disposition that the stuff has to combine with the colouring particles produces sometimes considerable changes in the manner in which the *mordant* ought to be employed; thus, when this disposition is great, we can mix the *mordant* with the colouring substance: the combination which is formed unites instantly with the stuff; but if it acts only by a weak affinity, the combination which is formed between the colouring particles and the *mordant* may be separated and precipitated before it is fixed upon the stuff. In order to prevent this inconvenience, it is necessary to begin by fixing upon the stuff the substance which is to serve as the intermedium between it and the colouring particles. From these observations, I shall deduce the explanation of the differences  
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which exist between the processes employed for dying black, and for dying wool or silk with cochineal.

Independent of the considerations which follow, it is necessary then, in order to judge of the effects of *mordants*, and of the most advantageous manner of applying them, to attend, 1<sup>st</sup>, To the combinations which ought to be formed, either by the action of the substances which compose them, or by that of the colouring particles, and of the stuff: 2<sup>d</sup>, To the circumstances which may concur in forming these combinations, more or less readily, and more or less completely: 3<sup>d</sup>, To the action the liquor may have in which the stuff is immersed, either upon its colour or texture; and in order to foresee what this action may be, it is necessary to know the proportions of the ingredients which enter into the composition of the *mordant*, and which ought to be set at liberty in the liquor.

*Mordants* are not taken from the class of salts alone: vegetable and animal substances serve mutually as *mordants* in certain circumstances; thus, in the process for dying the red of Andrinople, (which will be described in the second part), the cotton ought to be impregnated, or rather combined with an animal substance: thus, the astringent principle is frequently employed as an intermedium between the colouring particles and the stuff. Nobody has hitherto varied *mordants*, and the manner of applying them so much, as M. Poerner; and his works, in this respect, may be of great use, particularly the one which has been lately translated.



## CHAP. III.

*Of the action of different Substances, and particularly of Air and Light, upon Colours.*

WE have hitherto considered the colouring particles only as substances that can form different combinations, in consequence of which their properties are changed ; but they may be altered in their composition, either by external agents, or by the substances themselves with which they are combined. It is proper to begin, by examining the changes produced by external agents, because they are the most easily ascertained.

The property of resisting vegetable acids, alkalies, soap, and particularly the action of air and of light, constitutes the durability of a colour ; but this property is differently estimated, according to the nature of the colour, and according to the kind of the stuff ; for the same durability is not required in some colours of silk, as in those of wool.

There is nothing obscure in the action of water, acids, alkalies, or soap ; it is a solution produced by means of these agents ; and sometimes it appears that a small portion of the acid or alkali unites with the combination which forms the colour, since the colour is not destroyed, but changed only ; and we can restore it by saturating the acid, by means of chalk or ammoniac.

It is otherwise with the action of air and of light : till of late, it was not known in what their action consisted ;

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but at present much greater progress has been made in this subject; and we perceive that experiments only are wanting to enable us to arrive at a very accurate knowledge of it.

Scheele had observed, that the oxygenated muriatic acid rendered vegetable colours yellow; and he attributed this effect to its property of abstracting the phlogiston which entered into their composition.

I have shown \* that the properties of the oxygenated muriatic acid are owing to the oxygen that is taken from it by the substances on which it acts: that it generally changes the colouring particles to a yellow; but that, by a continued action, it destroys their colour, without ascertaining in what that action consists.

M. Fourcroy afterwards made many observations which throw much light on the changes that oxygen produces on colouring particles; chiefly when their aqueous solution is exposed to the air, or when boiled: he has observed, that by the action of air vegetable decoctions form pellicles which lose their solubility, and gradually change their colour: he has attended to the gradations of those that are obtained in that way; and he has concluded from his observations, that oxygen enters into the composition of the colouring particles; that when it combines with them their shades are changed; that the more they receive of it, the more fixed their colour becomes; and that the method of obtaining unalterable colours for painting, is to chuse those that have

\* Mem. de l'Acad. 1785,

have been submitted to the action of the oxygenated muriatic acid \*.

I have been particularly engaged in endeavouring to ascertain the action of air upon colours of different natures, by analysing that of the oxygenated muriatic acid † in a memoir, of which I shall give a short abstract.

It is necessary to distinguish, with regard to the effects of air, the colours of the metallic oxids from those of the colouring particles. I have proved, that the modifications of the first are entirely owing to their different proportions of oxygen, as I have said in the first chapter of this section: but I have been led by my observations to a very different opinion, with respect to the modifications of the other colouring particles.

I have observed that the oxygenated muriatic acid exhibits different appearances with the colouring particles; that sometimes it effaces the colour, and renders it white; that more frequently it changes it to a yellow, to a fawn, to a brown, and to a black, according to the intensity of its action; and that when the colour appears to be effaced or bleached, heat, or the lapse of time, are sufficient to render them yellow.

I have compared the effect produced by the oxygenated muriatic acid, when the colouring particles are rendered yellow, fawn, or brown, with the effects of

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\* Ann. de chym. tome V.

† Ibid. tome VI. Mem. sur l'action que l'acide muriatique oxygéné exerce sur les parties coloantes.

slight combustion, and I have found that they are perfectly the same; that they are owing to the destruction of the hydrogen, which, by combining with the oxygen more readily, and at a lower temperature than carbon, leaves it in a superabundant quantity, so that the colour peculiar to the carbon is more or less mixed with that which existed before.

This effect is very evident, when we subject sugar, indigo, an infusion of gall nuts, or of sumach, to the action of the oxygenated muriatic acid; the sugar and indigo assume a deep colour, and present unequivocal marks of slight combustion; the infusion of gall nuts, or of sumach, affords a black deposition, which is carbon almost pure.

These phenomena are similar to those observed in the distillation of an organized substance; in proportion as the hydrogen is disengaged under the form of oil, or in the state of a gas, the substance becomes yellow, and at last there remains only a black charcoal. If we expell hydrogen from an oil by heat, it becomes equally brown.

By other experiments which I have made on alcohol and æther, I have proved that the oxygen united with the muriatic acid possesses the property of combining, and of forming water with the hydrogen, which abounds in these substances.

When then the oxygenated muriatic acid produces a yellow, fawn, or brown colour, this is occasioned by the colouring substance undergoing a slight combustion, in which a greater or less portion of its hydrogen forms water, and then the carbon becoming the prevailing ingredient communicates its own colour.

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I have made it appear, that it is upon this change of the colouring particles by the oxygen of the atmosphere, by dew, and by the oxygenated muriatic acid, that the art of bleaching cloth is founded. The colouring particles of thread are rendered soluble by the alkaline ley, which ought to be alternate with the action of oxygen. We can afterwards separate from the alkali these colouring particles, which being dried and brought together, are black, and demonstrate the truth of this theory by the colour which they have assumed, and by the quantity of carbon which their analysis affords.

The alkaline solution of the colouring particles of a cloth that is of a dark brown, loses almost the whole of its colour, when a certain quantity of the oxygenated muriatic acid is poured upon it; and the same effect may be observed in many other substances that have assumed a colour which depends on the commencement of combustion.

A cloth may appear white, and yet become yellow in course of time; especially if it is subjected to a certain degree of heat, when it has not been deprived of its oxygenated particles by a ley sufficiently strong: in the same manner, the green parts of vegetables are bleached by the oxygenated muriatic acid, but they become yellow by boiling.

These acts prove that oxygen can whiten, or render the colouring particles paler with which it combines, whether it may have begun to produce the effects of combustion, or that it produces those effects afterwards in a gradual manner; and especially when their



combination is subjected to a considerable degree of heat.

It is very probable, that in all these cases, a part of the oxygen unites with the colouring particles without combining in a particular manner with the hydrogen; and that this is the reason why the colouring particles of thread become, by the action of oxygen, more soluble than formerly with alkalies.

The action of oxygen, in many other circumstances, has certainly much influence upon the changes which are produced in the colouring particles of vegetables: these particles are formed chiefly in the leaves, in the flowers, and in the second bark of trees: they gradually undergo a slight combustion, either by the action of the surrounding atmospheric air, or by that of the air which is carried into the interior parts of vegetables by the *vasa propria*: hence the greater part of trees contain colouring particles of a fawn colour, approaching more or less to a yellow, red, or brown, which by means of this combustion are thickened and at length thrown out of the vascular fibres of the bark, of which I find they form the greatest part.

These observations inform us in what manner the air acts upon colouring substances of a vegetable or animal nature: it at first combines with them, weakens them, renders them pale, and by degrees excites a slight combustion, by which the hydrogen that enters into their composition is destroyed; they become yellow, red, or fawn; their affinity with the stuff appears to be weakened, they are detached from it, they are carried along by the water, and all these effects vary and are produced more or less readily, and more or less

less completely, according to the nature of the colouring particles, or rather according to the properties they possess in that state of combination in which they exist.

The changes which happen in the colours that depend on the combination of the colouring particles with metallic oxids, are a compound effect of the change which is produced in the colouring particles, and of that which the metallic oxid undergoes.

The light of the sun accelerates much the destruction of colours; it ought then (if the present theory be just,) to favour the combination of the oxygen, and the combustion by that means produced.

M. Sennebier has made a great number of interesting observations with regard to the effects that light produces upon different substances, and particularly upon colours; he attributes these effects to a direct combination of the light with these substances \*.

The influence of light upon the colour of wood has been observed for a great length of time: in the dark, it preserves its natural state; but exposed to light it becomes of a yellow, a brown, and a variety of other shades. M. Sennebier observed the differences which occur in this particular between different kinds of wood: he found that the changes were proportional to the intensity of the light; that they took place even under water, yet that moistened wood underwent these changes less readily than dry; that several folds of ribbon were necessary to preserve the wood completely; that black paper was sufficient; but that

\* Mem. Physico chym. sur l'influence de la lumiere solaire. T. c. 24

the change was not prevented by other colours ; that a single fold of white paper was insufficient, but that two intercepted the action of light.

This learned philosopher has extended his experiments to a great number of vegetable substances, which may serve to explain many phenomena of vegetation that are foreign to our present subject. But in order to show the action of the sun upon colours, it will be sufficient to examine the phenomena exhibited by the solution of the green parts of vegetables in alcohol.

If we expose to the light of the sun this solution, which is of a beautiful green, it assumes an olive colour, which is afterwards in a few minutes destroyed : if the light has little intensity, the effect takes place much more slowly ; but in perfect darkness, the colour is preserved without change, or at least the change is very gradual. M. Sennebier says, that an alkali restores the green colour ; but if the liquor has once been completely destroyed, the alkali produces no change in it. He observed, that in azotic gas, or phlogisticated air, the colour was not changed ; and that it suffered no change if the jar was full.

I inverted in mercury a jar half filled with a green solution, and exposed it to the light of the sun : when the colour was destroyed, the mercury was found raised in the jar, and consequently vital air had been absorbed ; the oxygen had combined with the colouring particles. I did not observe the deposition which M. Sennebier mentions ; the liquor remained transparent, and was tinged of a clear yellow colour.

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I evaporated this liquor, its colour instantly became deep and brown, the residuum was black, and in the state of carbon.

The light then acted by promoting the absorption of oxygen, and the combination of the colouring particles: at first, the marks of combustion were not perceptible, the liquor had only a feeble yellow colour, but the combustion was soon completed by the action of heat; the liquor became brown, and left a black residuum. If the vessel in which the liquor is kept does not contain oxygenous gas the light has no action upon the colouring particles: the azotic gas does not suffer any diminution.

It is necessary to attend to an observation I have already made; ribbons, and a single fold of white paper, do not prevent the action of light. It can penetrate through coverings which appear to us opaque, and exert its influence to a greater or less depth.

Beccari, and after him M. Sennebier, have compared the effects that light produces upon ribbons of different colours; but the differences which they have observed ought rather to be attributed to the nature of the colouring substances with which the ribbons were dyed, than to the colours themselves; for a ribbon dyed with brasil wood will lose its colour much sooner than one dyed with cochineal, although the shade be the same.

Although light accelerates greatly the combustion of the colouring particles, and its presence even appears to be necessary to the destruction of some of them, yet in others this effect takes place without the assistance of light. Having placed in the dark, different

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ent plants in contact with vital air, I observed that some of them absorbed it. I also observed, that a rose was changed and assumed a darker tinge without the contact of air, evidently because it contained a small quantity of oxygen, the combination of which afterwards became closer; but many kinds of flowers preserved their colour perfectly in azotic gas.

I placed a quantity of the tincture of turnsole in contact with vital air over mercury in the dark, and another quantity in the light of the sun; the former remained a long time without alteration, and without the vital air suffering any diminution; the latter lost much of its colour and became red, the vital air was for the most part absorbed and formed a small quantity of carbonic acid, which evidently had changed the blue colour into a red.

This observation may give us an idea of some of the changes of colour that are produced by a particular disposition of the principles existing in a vegetable substance, when by its combination with oxygen it experiences the effects of a slight combustion that may give rise to some acid; in the leaves for example, which become red in Autumn before becoming yellow, and in the streaks that are observed in flowers that begin to languish.

It is then proved that light favours the absorption of oxygen by the colouring particles, and by this means combustion is produced, the common effect of which is a super-abundance of carbonaceous particles.

We must attribute to the same cause the destruction observed in stuffs themselves by the action of light. "Among many examples that I might quote,"  
says

says Dufay, “ I shall only mention a silk curtain of a  
 “ false crimson colour, which had remained for a  
 “ long time stretched out behind a window; all the  
 “ parts opposite to the panes of glass were completely  
 “ faded, while those that corresponded to the frame  
 “ were much less injured: besides this, the silk itself  
 “ was almost destroyed in the faded parts, and the  
 “ curtain was torn with the least force in these  
 “ places, while in others it preserved nearly its usual  
 “ degree of strength \*.”

An apparent contradiction here presents itself: it is to the action of the light of the sun that the production of vegetable colours is owing; it disengages oxygen from the nitric acid, from the oxygenated muriatic acid, from some metallic oxids, and from plants in vegetation; it produces then, to speak so, the opposite of combustion, and when it contributes to the destruction of colours, it serves to fix the oxygen, and to produce a kind of combustion. In the same manner phosphorus is not changed by the oxygenated muriatic acid in the dark, even with the assistance of heat; but it undergoes combustion, and is converted into phosphoric acid by the presence of light †.

I am ignorant what the circumstances and what the affinities are that produce at one time the one effect, and at another time the other, but both are equally certain. It appears to me that these phenomena may be compared to those of double affinities. It is certain that calcareous earth yields the sulphuric acid to  
 potash,

\* Mem. de l'acad. 1737.

† Mem. sur l'acide marin dephlogistiqué, 1735.

potash, and yet by means of an exchange, calcareous earth can expell potash from its combination with sulphuric acid.

I see, besides, in nature a great number of phenomena of the same kind ; thus, in spirituous fermentation the hydrogen is accumulated in the liquor, and by the progress of the same effect alone the proportion of the hydrogen is diminished ; it enters into combination with the oxygen, which becomes superabundant when the fermentation passes to the acid state. The putrefaction which takes place in animal substances may be considered as an operation opposed to the phenomena of growth and nutrition.

Colouring substances resist then the action of air, in proportion as they are more or less disposed to combine with oxygen, and to undergo by its action combustion more or less readily, and in a greater or less degree. The light promotes this combustion, and in many cases it does not take place without its assistance ; but isolated colouring particles are much more disposed to undergo this combustion than when they are combined with any substance, such as alumine ; whether it be that this defends them by its incombustibility, or to speak so, that it restrains the force of their affinity, and weakens their action upon other substances ; it is in this that the utility of *mordants* chiefly consists. In short, this last combination acquires a still greater degree of unalterability when it is intimately combined with the stuff.

Thus the colouring part of cochineal is readily dissolved in water, and is speedily changed by exposure to the air ; when it is combined with the oxid of tin,  
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is of a much more lively colour, and becomes almost insoluble in water; but it is still easily changed by the air, and by the oxygenated muriatic acid, and it resists these agents better when it forms a triple combination with a piece of woollen stuff.

We must not conclude from what has been said, that all yellow colours are owing to the carbonaceous part of colouring substances: very different compositions may produce the same colour; thus, indigo is very different from the blue of flowers, from the blue of the oxid of copper, and from Prussian blue.

I do not assert that oxygen cannot unite with certain colouring particles in a small quantity, without weakening their colour, or changing them to a yellow. We shall see in the chapter on indigo, that it has a green colour when it is combined with an alkali, with lime, or a metallic oxid; but that it resumes its colour, and is separated from these solvents in recovering a small portion of the oxygen which it had lost. The liquor of the *buccinum*, which is employed to dye purple, is naturally of a yellowish colour, upon being exposed to the air, and especially to the sun, it passes readily through different shades and assumes at last the colour that was so precious among the ancients\*.

We may consider it as a general fact, that colours acquire a greater degree of brightness, by combining with a small quantity of oxygen; it is on this account that

\* Decouverte d'une nouvelle teinture de pourpre, &c. par Reaumur. Mem. de l'acad. 1711. According to the testimony of Eudocius the purple acquired its brightness, and arrived at perfection by exposing it to the rays of the sun.



that it is necessary to agitate in the air stuffs which come out of the dying vat, and sometimes to take them out at proper intervals to expose them to the air; but the quantity of oxygen which is fixed, and which contributes in this manner to the brightness of colours, is very inconsiderable in some, and the fading very speedily commences.

The action of the air does not alter the colouring particles, and the stuff alone: it extends to metallic oxids when they are used as auxiliaries, because the oxids, which are at first deprived of a part of their oxygen, may recover it again, as we shall see when we come to explain the action of astringents.

Those which have a colour varying according to the proportion of oxygen, have a considerable influence upon the changes that the colour undergoes. The change observed in the blue produced on wool, by means of sulphate of copper and logwood, is evidently owing to this cause.

This blue is changed very quickly to a green by the action of air; for we know that copper, which has a blue colour when it is combined with a small portion of oxygen, acquires a green by combining it with a greater quantity of this principle. Indeed the change that the colouring particles undergo may contribute to produce this effect; but the colouring particles of logwood, which are naturally of a deep colour, ought during combustion to become brown rather than yellow, which would be necessary to produce green with blue.

I have said that colouring particles which are in a state of combination, are less disposed to be altered by

by the action of the air than when they are uncombined. This in general holds true. There are, however, some exceptions: alkali produces a contrary effect. I put an infusion of cochineal in a jar, which I filled half full, and exposed to the light over mercury. A similar jar contained an infusion of cochineal made with a small quantity of tartar; and in a third jar I added to the infusion a small quantity of alkali: the infusion in the second jar suffered the least alteration, and in it also the least absorption took place.

In the third, the liquor at first assumed a brown colour, which was afterwards destroyed; and the absorption of air, although inconsiderable, was greater than in the other two. I had it evaporated; it assumed a brown colour, and the residuum was of a yellow brown.

I have made similar experiments upon many colouring substances: an alkali deepens their colour which becomes darker, and it promotes the absorption of air. Madder alone appears to be an exception to this: its colour, which at first becomes very deep, is better preserved than that of the infusion made without the alkali.

The common effect of the alkali upon the colouring particles is similar to that which it produces upon many other substances, such as sulphur; it promotes the absorption of the air, because it has a strong affinity with the result of this absorption.

I explain by this action of the alkali an observation of M. Becker's, which is, that when an alkali has rendered a vegetable infusion green, we see it gradually become yellow if we allow it to remain exposed to the air, and when once the yellow is formed, acids cannot  
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bring back the primitive colour again; but the same thing does not take place when we expose, during the same time, a vegetable colour that has been changed to a red by means of an acid. It is necessary, however, to except acids which may act by parting with their oxygen, as we shall immediately see, for then the colour is equally destroyed.

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#### CHAP. IV.

*Of the yellow colour produced in animal substances by the nitric and oxygenated muriatic acids.*

THE action which the nitric and oxygenated muriatic acids exert upon animal substances, has such a relation to the subject of the preceding chapter, that I have thought it proper not to separate them, although the yellow colour which is produced by these acids upon wool, and particularly upon silk, might deserve a place among the processes of the art.

M. Brunwiser \* having observed that wood assumed different colours by exposure to the air, endeavoured to ascertain from what source these colours originated, and to produce them artificially: he observed, that by moistening the surface of wood, especially young wood, which is not thoroughly dried, with

\* Versuche mit mineralischen sauern geistern auf den holzern farben zuziehen. 1770, in abhandlungen des Baierischen Academie.



with the nitric acid, and it assumed a yellow colour; and that by repeating the same operation with the muriatic or sulphuric acids it assumed a violet colour, and he considered this violet as composed of a blue and a red colour. From these observations he concludes, that since all colours are produced by the mixture of yellow, of blue, and of red, therefore those which are observed in leaves, fruits, and flowers, must be owing to colouring particles which exist in the wood, and are concealed there by an alkali: that the mineral acids, by seizing upon this alkali, set the colouring particles at liberty; and that fixed air, by penetrating the leaves, fruits, and flowers, produces naturally the same effect by combining with the alkali that kept these particles concealed. This author has endeavoured to apply his experiments and supposed discovery to the arts\*. After having moistened chips of wood with the nitric acid, he poured water upon them, filtrated the liquor, and employed it for dying stuffs made of wool, of silk, and goats hair, of a durable yellow; which is produced, according to him, by the yellow colouring particles contained in the wood being extracted or set at liberty by the nitric acid.

De la Folie relates †, that having plunged a skain of white silk into the nitric acid, or aquafortis, of the degree of concentration at which it is sold in the shops, in three or four minutes it took on a beautiful jonquil yellow colour: he washed it repeatedly with water,

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\* Entdeckung verschiedener vegetabilischen farbematerialen seiden und wollen zeuge schon und dauerhaft gelb zu farben 1771.

† Journal de Phys. T. IV. p. 349.



lest it should be altered by the acid that might remain adhering to it. This colour sustained several trials to which he subjected it, and the silk preserved its lustre entire. When dipt into an alkaline solution, it assumed a beautiful orange colour.

We find many experiments upon this process, in a dissertation published by M. Gmelin\*: he says, he gave a beautiful sulphur colour to silk by keeping it for a day in cold nitric acid, or for a few hours when the acid was warm. Boiling with soap water diminished the brightness of this colour. It was changed to a fine citron colour by keeping the silk for twelve hours in an alkaline solution, and it assumed a beautiful golden colour when this solution was warm.

All metallic solutions by the nitric acid give to silk a yellow colour more or less deep, as well as the solution of alumine by the same acid; but the solution of calcareous earth, or of magnesia, produces no effect.

This solution, mixed with the solution of gold, affords, according to la Folie †, a purple colour, that is fixable upon silk; but M. Gmelin obtained by this process only a common yellow. He proves also, that the different yellows which M. Struve had said were obtained from metallic solutions ‡ are owing entirely to the acid of these solutions; the only exception that ought perhaps to be made is, with respect to the solution of mercury, which gives a copper colour to silk.

Bergman

\* J. Frieder. Gmelin, prof. Gotting, de tingendo per nitri acidum, sive nudum, sive terrâ aut metallo saturatum serico. Erfurti 1785.

† Journ. de Phys. T. VIII.

‡ Bernerisches magazin der naturkunst und wissenschaften, vol. I.

Bergman was acquainted with this process when he published his notes to the treatise of Scheffer\*: he says, that common aquafortis gives to wool and to silk, in three or four minutes, a clear, beautiful, and durable yellow; that it is necessary to wash them both immediately, and that the more the acid is dephlogisticated, the greater is the effect that is produced.

From the first experiments that I made upon the oxygenated muriatic acid, I found it had also the property of giving a yellow colour to animal substances; but it gave them a colour much less deep than the nitric acid, and it injured them much more than this acid when properly diluted with water, so that the nitric acid is greatly preferable for the purposes of art.

To resume these observations; the nitric acid, diluted with a certain quantity of water, gives to silk a yellow colour, more or less deep, according to the concentration of the acid, the temperature, and the longer or shorter time of immersion; it is necessary to wash the silk carefully on taking it out of the acid: this colour has a sufficient degree of brightness: it may be rendered deep without any visible injury to the silk, so that this process may be of real use. The colour may be modified by alkalies.

The solutions of calcareous earth, or of magnesia, produce no effect upon silk, because they do not contain an excess of acid; the solution of alumine, and those of all metallic substances, produce, on the contrary, a darker or lighter yellow; because they all contain

\* Essai sur l'Art de la Teinture.

tain a greater or less excess of acid, which acts upon the silk in the same manner as a free acid : it was the acid alone, therefore, which gave the yellow colour to animal substances in the experiments of M. Brunwiser, and not the particles extracted from the wood.

The yellow colour is not owing to iron, as de la Folie has alledged ; for the purest nitric acid, which of consequence contains no iron, produces it as well as that in which a small quantity of this metal is supposed to exist.

If we put silk into concentrated nitric acid, it readily assumes a deep yellow colour, loses all its force of adhesion, and is dissolved : during this solution, the azote, which enters into the composition of animal substances, is disengaged, and occasions a tedious effervescence \* : if we apply heat, a great quantity of nitrous gas is disengaged, and at the beginning the liquor assumes a deep colour, and becomes brown. At this time the oxygen of the nitric acid combines unquestionably with the hydrogen that abounds in animal substances, which assists in forming the oil we obtain from them in distillation, and which renders them so inflammable. The same effect ought to take place when the acid begins to act upon the silk and to render it yellow. I believe, therefore, that the yellow colour arises from an incipient combustion, as I have explained in the preceding chapter. This slight degree of combustion does not injure the silk in any sensible manner ; but if the acid is too much concentrated, if the immersion is continued too long, or if

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\* Mem. de l'Acad. 1785.

we do not remove, by a careful washing, whatever might adhere to it, the silk is soon very much injured, and, according to common language, which affords a very just idea, *it is burned*.

We can now perceive why, according to the observation of Bergman, thenitrid acid, which he called the dephlogisticated, is for this operation to be preferred to that which is saturated with nitrous gas : for in the former the proportion of oxygen being greater, it is on that account more fit to produce the effects of combustion until it is brought back to the state of nitrous acid.

The same circumstance ought undoubtedly to explain the action of the oxygenated muriatic acid upon animal substances ; yet it differs in some essential points, all of which I cannot explain, as they require a great number of observations.

Silk assumes, with the oxygenated muriatic acid, a colour much lighter than with the nitric : the sulphurous acid causes it in a great measure to disappear, but it has no action upon the yellow produced by diluted nitric acid. The oxygenated muriatic acid has, however, a much more lively action upon silk : it quickly injures it, and even dissolves it : if we allow the silk to remain some time in this liquor, the yellow, which at first appears, is weakened, agreeably to the observation I formerly made, that the yellow colour, which is owing to the combustion first produced, may be disguised by the accumulation of oxygen.

By the readiness with which the sulphurous acid parts with its oxygen, I once endeavoured to explain \*

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\* Suite des Exper. sur l'acide sulfureux. Ann. de Chym. tom. II.



the effects it produces upon colours, and I compared them to those of the oxygenated muriatic acid; and although it be true that oxygen adheres much more weakly to the sulphurous than to the sulphuric acid; yet I do not believe that the explanation I gave is well founded.

According to the observation of de la Folie \*, roses whitened by the vapour of burning sulphur, become green in an alkaline ley, and red in acids. I have myself observed, that the sulphurous acid reddens the tincture of tournsole, which has a very fleeting colour, and that it acts only like other acids upon infusions of yellow wood, on fernambouc, and logwood. I have besides observed, that silk which has been exposed to the vapour of sulphur, exhales the odour of sulphurous acid, when we moisten it with the sulphuric, although this odour was not formerly perceptible.

I think then, that the sulphurous acid combines generally with the colouring particles and with silk, without parting with its oxygen to them, and consequently without combustion taking place; that the result of this combination sometimes loses all colour, a property depending probably on the semi-elastic state of the oxygen; but sometimes the combustion may take place, and it ought in general to do so by degrees; so that the colouring particles, after having been long concealed, will at last assume a yellow colour. This subject I think might easily be elucidated by some experiments.

CHAP.

\* Journ. de Phys. 1774.

## CHAP. V.

*Of Astringents in general, and particularly of Galls.*

ASTRINGENTS deserve particular attention, not only because they are of great use in dying, but because they exhibit a property common to a great number of vegetables.

There is, perhaps, no property in vegetables of which we entertain such vague ideas as of this ; we often judge of it from a weak resemblance in the taste, and both in medicine and in the arts under the name of astringent, we rank alum and many vegetables, the properties of which are, however, exceedingly different : in general, we consider as an astringent, every substance which gives a black colour to a solution of iron ; we suppose, that this effect is owing to one and the same principle existing in all the substances which produce it : we apply the term astringent to this principle, and at present it is considered as a peculiar acid to which we give the name of gallic acid, from the gall nut in which it exists.

However, several learned chemists have of late made a great number of interesting observations upon astringents. I shall now present an abstract of them ; but as the gall nut has been the usual subject of these observations, it is necessary to begin by describing it.

The gall nut is an excrescence which is found upon the young branches of the oak, particularly on the species that we call the hard oak, which grows in the Levant, Istria, Provence, and Gascony. This excrescence

cence is produced by the bite of an insect, which deposits its eggs in the small incision it makes in the Spring; the juice which transudes from this wound thickens, accumulates, and serves as a shelter to the young insect, until it be able to make its escape: when the insect does not obtain an outlet, we find it dead in the gall nut: sometimes after it has quitted its habitation, other insects enter and occupy it.

There are different kinds of gall nuts; some of them are white, yellow, green, brown and red; others are ash-coloured and blackish; they vary greatly in size; they are round or irregular, light or heavy; some of them are smooth, and others are covered with knobs: those which are small, knobby, blackish, and heavy, are the best: it is these last that are known by the name of the galls of Aleppo, and they are brought from Aleppo, Tripoli, and Smyrna.

Galls are almost entirely dissolved by long boiling: sixteen drachms afforded to Newman fourteen drachms of extract; alcohol dissolved only four grains of the residuum, which weighed two drachms.

The same quantity, infused first in alcohol, and afterwards in water, afforded twelve drachms two scruples of a spirituous, and four scruples of an aqueous extract; the residuum weighed half a scruple more than in the preceding experiment. The spirituous extract had a stronger and more disagreeable taste than the other\*.

M. Monnet, to whom chemistry is indebted for a great number of important observations †, considers  
Macquer

\* The chemical works of Caspar Newman, by William Lewis.

† *Traité des Eaux minérales*, p. 304.

Macquer as the first who attributed the formation of ink to a precipitation of iron by the astringent principle, the theory of which he has himself established; he imagines that the iron has a greater affinity to this principle than to the acid with which it was united; but the acid dissolves a part of the precipitate, provided it be not too much diluted with water.

Iron is not the only metallic substance which may be precipitated from its solvent by the astringent principle: M. Monnet has observed, that gold, silver, copper, zinc, cobalt, platina, and mercury, are also precipitated by it.

The metallic substance the most easily precipitated is mercury: its solution mixed with an infusion of galls assumes a brick colour, but the precipitate which is formed soon becomes of a reddish grey.

Copper is very readily precipitated: the precipitate is at first green, but it becomes of an ash-coloured grey, and in drying assumes a reddish coppery gloss.

Zinc forms a green ash-coloured precipitate.

The precipitate of cobalt is of a clear blue; but it does not preserve this colour long, for it soon becomes of an ash-coloured grey.

Silver is precipitated very slowly: the precipitate, which is at first of the colour of burnt coffee, assumes, when dried on paper, a shining silvery lustre.

Gold is precipitated almost insensibly: the precipitate, when collected and dried, is in every respect similar to that of Cassius.

M. Monnet collected the precipitate of iron by the astringent principle upon a filter: it was of a beautiful deep blue: he thinks it might be employed with advantage



advantage in painting. He tried to dissolve it in the nitric and sulphuric acids, but they acted upon it very slowly ; having accelerated their action by heat, he obtained by filtration beautiful yellow tinctures, especially that of the nitric acid, which resembled a solution of gold : no precipitation took place, and the liquors remained always clear and limpid : alkali occasioned no precipitation ; it produced only a deeper colour. M. Monnet was led by this observation, to dissolve this precipitate directly in a solution of fixed alkali by means of boiling ; he obtained a solution as red as blood, in which water produced no precipitation.

The academicians of Dijon have added to these facts several interesting observations.

Galls afford by distillation, a limpid phlegm, which gradually becomes brown, then a yellow oil, after that an oil deeper in colour, and empyreumatic. All these liquors afford a black precipitate with the sulphate or vitriol of iron ; the carbonaceous residuum has no longer any peculiar property ; it reddens in the fire without being reduced to ashes.

Even cold water dissolves the astringent principle : an ounce of galls afforded by this means three drachms of a nondeliquescent and very styptic extract.

Fixed and volatile oils and æther dissolve the astringent principle.

The infusion of galls gives a red colour to blue paper, and the tincture of tournsole ; but it has no action upon syrup of violets.

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The sulphuric acid receives from galls a red colour; the nitric an amber, and the muriatic a brown: these three acids precipitate the sulphate of iron of a black colour, when they are saturated with alkalies.

The acetous acid loaded with the astringent principle, does not require this addition of alkali to give a black precipitate.

The phosphoric acid produces no change upon the infusion of galls; but this mixture renders the solution of sulphate of iron muddy, and a white precipitate is formed.

The sulphure of alkali is decomposed by the infusion of galls: in filtrating the liquor afterwards, the residuum does not precipitate the iron of a black colour, but the liquor that passes through the filter produces this effect; it appears to be a combination of alkali and of the astringent principle.

The carbonate of fixed alkali gives a reddish colour to the infusion of galls: this mixture forms a brown precipitate with the sulphate of iron.

The caustic alkali gives a red brown colour to the infusion of galls; and precipitates, at the same time, the sulphate of iron of a black colour: this precipitate when properly washed is not attracted by the magnet: it dissolves without effervescence in the mineral acids, but is not acted on by the acetous.

The mixture of the prussiate of alkali, and of the tincture or alcohol of galls, affords a black precipitate with the solution of iron: the sulphuric acid at first augments the intensity of the colour, and at last destroys it.

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The same work contains a great number of observations upon the precipitation of metallic substances by the astringent principle: galls do not alter the solutions of arsenic in any degree; and the oxid of this metal, mixed with an infusion of galls, does not prevent its action upon iron. The astringent principle forms ink with all the acid solutions of iron, except those of the phosphoric and arsenical acids.

To conclude; we find in that work some experiments upon ink, and upon the deposition which it affords when largely diluted with water. Ink is not decomposed by the acetous acid, but the mineral acids quickly deprive it of its colour; the sulphuric acid produces heat in it without effervescence; the liquor becomes yellow, and forms a greyish deposition. Alkalies restore the colour that acids have made to disappear, but by repeating the alternate action of the acids and alkalies, the colouring principle is at length destroyed.

The same academicians have observed another fact, which may become important, and upon which we shall afterwards see M. Laval has bestowed more attention; it is the action of galls upon iron. A cold infusion of them gives a violet tinge to iron filings, but by boiling them together, a part of the iron is dissolved, and the liquor assumes a violet colour, which approaches much to a black.

M. Laval says, he long ago observed, that galls infused in distilled water alone, dissolve iron with the greatest readiness; that with a simple solution of this metal in an infusion of galls, he not only produced the deepest black colour, and the most indelible ink,  
but

but also, by plunging silks and woolen stuffs into this black tincture, he dyed them, without the addition of any acid, of the deepest and most indestructible black.

Dr Priestley obtained inflammable, or hydrogenous gas, from a mixture of iron filings, powdered galls and water: this experiment proves, that galls act upon iron like acids, by promoting the decomposition of water, and the consequent disengagement of its hydrogenous gas.

Even before M. Monnet ascertained the manner in which the astringent principle combines with the iron, and forms the black colouring particles which may be precipitated, Dr Lewis had made some interesting observations upon this combination, which he endeavoured to render peculiarly useful in the arts.

He observes, that if we dilute common ink with a sufficient quantity of water, the black is precipitated, and the liquor remains clear; he remarks, that it is this black part which is fixed upon stuffs, and which serves to colour them: he endeavoured from this to determine the most convenient proportions of the astringent, and of the solution of iron, both as to the quantity of the black precipitate, and as to its quality.

The experiments of Scheele have such an influence on the opinion that is formed concerning the nature of the astringent principle, that I shall relate them in his own words:

“ I passed through a large sieve a pound of galls,  
“ and infused the powder with 2 and 3-4ths pints  
“ of water in a glass globe. I allowed it to remain in  
“ that state four days, during which time it was frequently stirred with a glass reed. I filtrated the li-  
“ quor



“ quor, which was clear, and of the colour of French  
“ wine: I exposed it to the open air in the same glass  
“ globe, covered only with a bit of grey paper. This  
“ preparation was made in the month of June. A  
“ month afterwards I again looked at this infusion,  
“ and I found it covered with a thick mouldy pelli-  
“ cle; there was no precipitate formed, and it had a  
“ more acid, but not more astringent taste than for-  
“ merly. I replaced this infusion in the same globe,  
“ covered as formerly with grey paper. Five weeks  
“ after this I examined it again; almost one half of it  
“ was evaporated. I found a precipitate two inches  
“ in thickness, and on the surface a mucous pel-  
“ licle; it had lost wholly its styptic taste, although  
“ it still gave a black colour to the vitriol of iron. I  
“ filtrated the infusion, and exposed it once more to  
“ the open air: by the following Autumn the great-  
“ est part of it was evaporated; what remained was  
“ mixed with a great quantity of precipitate. I mix-  
“ ed all these precipitates together, and poured cold  
“ water upon them; after they had been deposited, I  
“ decanted off the liquor, and poured on as much  
“ warm water as was necessary for their solution.

“ I filtrated the whole; the liquor was of a brown  
“ yellow; I evaporated it with a gentle heat; during  
“ the evaporation a part like fine sand was precipita-  
“ ted; another part formed crystals at the bottom  
“ disposed towards the light; this salt was of a green  
“ colour, and notwithstanding repeated solutions and  
“ crystallizations, it was impossible to procure it  
“ whiter.

“ This salt of galls has the following properties:

“ I.

“ 1. It has an acid taste : effervesces with chalk,  
“ and gives a red colour to the infusion of tournsole.

“ 2. An ounce and a half of water are required  
“ to dissolve half an ounce of this salt completely ; but  
“ as soon as the solution becomes cold, the whole  
“ forms a concrete mass, composed of small crystals.  
“ Half an ounce requires twelve ounces of cold water  
“ to dissolve it.

“ 3. It dissolves very readily in spirit of wine : for  
“ half an ounce of this salt, only the half of boiling  
“ spirit of wine is necessary ; but if we use cold spirit  
“ of wine, two ounces are required for half an ounce  
“ of the salt.

“ 4. It burns readily in an open crucible on the  
“ fire, and in melting exhales an agreeable odour ; but  
“ it afterwards affords a charcoal that is with diffi-  
“ culty reduced to ashes.

“ 5. Distilled in a retort it becomes at first fluid,  
“ and affords an acid phlegm. No oil comes over, but  
“ towards the end a white sublimate rises which at-  
“ taches itself to the neck of the retort, and remains  
“ fluid as long as it is warm ; but it afterwards crystal-  
“ lises ; we find in the retort a great quantity of char-  
“ coal. This sublimate has almost the smell and taste  
“ of the benzoic acid, or salt of benzoïn : it dissolves  
“ as readily in water and in spirit of wine ; it reddens  
“ the infusion of tournsole ; and, what is very remark-  
“ able, it precipitates metallic solutions of their differ-  
“ ent colours and the vitriol of iron of a black.

“ 6. The solution of the salt of galls poured into a  
“ solution of gold, gives it a dark green colour, and

“ at

“ at last a powder is precipitated, which is the gold  
“ revived.

“ 7. The solution of silver becomes brown, and  
“ deposits by heat a greyish powder, which is the sil-  
“ ver revived.

“ 8. The solution of mercury is precipitated of an  
“ orange yellow.

“ 9. The solution of copper affords a brown pre-  
“ cipitate.

“ 10. The vitriolic solution of iron becomes black;  
“ the more water that is added, the colour becomes  
“ deeper.

“ 11. Lead dissolved in vinegar is precipitated of a  
“ white colour.

“ 12. Bismuth gives a yellow citron precipitate.

“ 13. The molybdenic acid becomes of an ob-  
“ scure yellow colour, without affording any precipi-  
“ tate.

“ 14. Platina, zinc, the arsenical acid, tin, cobalt,  
“ and manganese, do not suffer any change.

“ 15. The solutions of lime, magnesia, alumine,  
“ and barytes, are not decomposed, but lime-water  
“ affords a copious gray precipitate.

“ 16. The salt of galls is converted into the sac-  
“ charine acid by distilling nitrous acid upon it in the  
“ usual manner.

“ The white precipitate that we obtain when the  
“ acetite of lead is precipitated by galls, may be again  
“ decomposed by the vitriolic acid, and we obtain the  
“ salt of galls in its greatest purity: however, as the  
“ infusion of galls precipitates the acetite of lead, I  
“ thought I should have been able to have procured  
this

“ this salt in a manner still more expeditious ; but  
“ this did not succeed ; for when I had decomposed  
“ this precipitate by means of the vitriolic acid,  
“ I again found my infusion of galls possessed of  
“ its ordinary astringent taste. If we distill galls with  
“ a violent fire, we obtain an acidulated phlegm, the  
“ odour of which is not disagreeable : no oil passes  
“ over ; but towards the end a volatile salt rises, simi-  
“ lar to that obtained from the distilled salt of galls,  
“ and possessed of the same properties. From this it  
“ appears, that this salt exists completely formed in  
“ the infusion of galls, although it cannot be obtain-  
“ ed by means of ordinary crystallization ; for it is so  
“ intimately combined with some mucilaginous or  
“ other matter, that it cannot be separated without  
“ an internal commotion, or without fermentation.”

These experiments of Scheele have induced the greater part of chemists to consider the gallic acid as the astringent principle, and to conclude that it exists in all vegetable substances which precipitate solutions of iron of a black colour ; that this precipitate is a combination of the gallic acid, and of the iron which quits the other acids to unite with it.

I have repeated and varied the experiments of Scheele upon galls, and I have observed, 1. That by following the process pointed out by this great chemist there were green pellicles successively formed, owing to a *byffus* which could not be produced in a vessel well stopped. -

2. That in a similar vessel where evaporation could not take place, pure, transparent, and yellow crystals were deposited during the Winter, without



the influence of the external air, and that consequently the gallic acid exists in the galls, and is not produced by the absorption of oxygen, as I had formerly conjectured.

3. That if we evaporate one half of the liquor before shutting it up in the vessel, it assumes a deep colour during the evaporation, and deposits afterwards a great quantity of a crystalline substance, but less pure, and of a deeper colour.

4. That the acid obtained in this manner, or by the process of Scheele, and afterwards dissolved in water, is always decomposed by evaporation; that black pellicles are separated from it; that it becomes brown by simple exposure to the air; that, after repeated operations, nothing more is obtained than an ill-formed crystallization of a grey colour, more or less yellow or brown; and that if the evaporation is repeated a number of times, this salt is completely destroyed. Heat, and especially boiling, accelerate this destruction: this is the true reason, I believe, why this salt is not obtained by evaporating the decoction of galls: an extract then remains which resembles perfectly that of galls, and which suddenly precipitates solutions of iron of a black colour.

5. The solution of the gallic acid assumes a fine green colour with the fixed and volatile alkalis, either free or combined with the carbonic acid; and this colour becomes so deep, that it appears black if the gallic acid and the alkaline solution are brought together: with lime water the gallic acid assumes a reddish brown colour, the red tinge is dissipated, and

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a copious deposition takes place of a grey colour, approaching to brown.

In the mixture of the gallic acid with the carbonate of alkali, I have not observed an effervescence, any more than with the carbonate of lime or of magnesia: but this substance reddens the tincture of tournsole, of radishes, &c. like acids.

6. The infusion of common galls produces the same effect upon vegetable colours as the gallic acid, but the infusion of white galls has no action upon them.

Paper tinged with tournsole is not altered by the infusion of sumach, of the bark of the plumb-tree, of the bark of the walnut, or of Peruvian bark.

Having made four successive decoctions of galls, which had previously undergone Scheele's process, the two last did not redden paper tinged with tournsole, although they precipitated copiously the solutions of iron. By spontaneous evaporation I could perceive no mark of the gallic acid in the two last decoctions.

7. A solution of the sulphate of iron, mixed with a solution of the gallic acid of the highest possible degree of purity, is not disturbed, and does not assume any colour at first; it is only by degrees that it becomes black, without losing its transparency, or at least it does not begin to lose it till after some hours: a small quantity of the infusion of galls produces instantaneously a colour much more intense and opaque.

These observations prove, in a satisfactory manner, that it is not the gallic acid that communicates the astringent property to the substances which possess it: that this acid itself possesses this property in a lower degree than other astringents.

Indeed the sumach, which is managed like galls by Scheele's process, does not afford any gallic acid, although it possesses the astringent property in a high degree; the green shell of nuts treated in the same manner also gives none. It appears that the property, which the infusion of common galls has of reddening certain vegetable colours, depends entirely on the gallic acid; since the infusion of sumach, that of the bark of the plumb-tree, which readily afford a black precipitate, the infusion of the bark of the walnut, and of the Peruvian bark, do not possess this property; and from this it appears, that the gallic acid does not exist in white galls. The infusion of white galls exposed to the air may readily deceive us; for it forms a copious precipitate, but this is not the gallic acid.

If the astringent property were owing to one and the same principle, distributed among different vegetables, the precipitates that are obtained by their means from a solution of iron should be the same combination, and should present the same appearances and the same properties: but it is quite otherwise; the precipitate produced by galls is of a blackish blue; that from logwood has another shade of blue; that from the oak is of a fawn, or blackish brown; that from the Peruvian bark of a blackish green: the circumstances which attend their deposition are different, and when fixed upon stuffs, some of them are destroyed much more readily than others by alum and tartar. It cannot be doubted, that by multiplying the experiments, we shall still find many remarkable differences among the properties of these various precipitates.

Astringents then form different kinds of combinations

tions with iron, and consequently their astringent property does not depend upon one and the same principle existing in different vegetables; still, however, there must be some property common to these different substances, which enables them to act in the same uniform manner upon solutions of iron, and to produce precipitates, which being more or less black, appear to be of the same nature, at least when not examined with attention.

I have observed, in analysing the effects of *mordants*, that metallic oxids, by combining with the colouring particles, modify their colours; but the colour of some metallic oxids, and particularly of the oxid of iron, varies according to the quantity of oxygen which they contain. Iron combined with only a small portion of oxygen is of a black colour, and forms what we call martial æthiops. It is sufficient that a substance, in combining with an oxid of iron, be able to separate from it a part of the oxygen which it retains, when precipitated from an acid solution, in order to give it a black colour; and if the particular colour of this substance does not predominate, or if it approaches to black, the combination which is formed will be black also.

Thus nitrous gas, free, or weakly combined in the nitrous acid, blackens the solutions of iron, as I have already shown \*, and it precipitates this metal by depriving it of a part of its oxygen.

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\* Mem. de l'acad. 1785, p. 338. The cause of the production of black by the gallic acid, has not escaped the sagacity of M. Fourcroy; "it colours iron," says he, "because it makes it approach to the metallic state."



It is also by acting in this manner that ammoniac forms a black precipitate with the solutions of iron ; for the hydrogen of the ammoniac forms water with the oxygen that is taken from the oxid of iron.

But galls, according to the observations of M. Monnet, and the academicians of Dijon already quoted, precipitate silver and gold from their solutions, by restoring them to the metallic state. They have then the property of abstracting oxygen from those metals to which it adheres slightly, and of taking from others the portion that is least intimately combined.

The infusion of galls itself assumes readily a deep brown colour, by remaining exposed to the air ; however, I have found that it does not absorb much oxygen. The infusion of sumach, and those of most other vegetable substances, particularly of woods and barks, assume in the same manner a brown colour by exposure to the air : so that by acting upon the oxid of iron, and by abstracting a part of its oxygen, an astringent ought itself to assume a brown colour which must concur in producing the black.

We see then, why many substances, which in other respects have different properties, may produce black with the solutions of iron. Among these substances, there are some which have true colouring particles, and which are employed as such in dying : for example, logwood, and even the greater part of colouring particles, form brown or blackish precipitates with iron. Sometimes the astringent effect is not instantaneous, but only produced by degrees ; the colour of the precipitate is at first clear, it deepens, and becomes  
brown

brown gradually, in proportion as it loses its oxygen: we observe this in the infusion of yellow wood; with a solution of iron, it forms a yellow precipitate, which gradually becomes brown, and afterwards black,

Although the property of precipitating solutions of iron of a black colour, does not announce the existence of one and the same principle in the substances which possess it, yet it may not be improper to express it by the name of the astringent principle, provided we understand by this word only a property common to a great number of substances, and a property which may exist in them in very different degrees.

The astringent principle precipitates iron from almost all acids; it appears from the experiments of the academicians of Dijon, that the phosphoric and arsenical acids alone, have a greater affinity with it than the oxid of iron, and we know that the phosphoric acid has the property of separating iron from the sulphuric acid; but all acids re-dissolve this precipitate, and make its colour disappear until they be saturated with an alkali, except the acetic acid; and probably the other vegetable acids that have not yet been tried.

We need not be surprised, that the astringent principle can combine with metallic oxids without possessing the qualities of an acid; for animal substances, oils, and even alkalies, and lime, have the same property.

It is this precipitate composed, of iron and the astringent principle, which, by remaining suspended in the liquor, forms ink; an object that is sufficiently interest-

ing both on its own account and its connection with dying black, to arrest our attention for a moment.

When we pour a small quantity of the solution of iron into an infusion of galls, at first we perceive the liquor become black at the point of contact; but the precipitate which is formed, is re-dissolved in the astringent liquor; by continuing to pour a sufficient quantity of the solution of iron, all the liquor becomes black, and loses its transparency; if in this state we dilute it with a very great quantity of water, the precipitate is gradually deposited, but the deposition is very slow in forming, when we use only a small proportion of the solution of iron; on the contrary, it forms much more readily, if we employ a quantity of the solution of iron so great, that all the astringent principle may combine with it. A superabundance of the sulphate of iron also accelerates this effect. The same phenomena take place here which are observed in other precipitations. The precipitate which is formed is soluble to a certain degree in the astringent solution; when the solution is farther advanced, the precipitation begins; but the precipitate is still kept suspended until the action of the astringent principle is sufficiently weakened by the admixture of water; if the iron is in a quantity sufficient to exhaust the action of the astringent principle, the precipitate is not retained, but deposited much more quickly.

The gum we add to ink opposes the deposition of the colouring part; it serves to fix more of this colouring part to a single stroke of the pen, to prevent it  
from



from running, and to preserve it from the action of the air. The gum of the cherry and plumb trees, according to Lewis, answers as well as gum-arabic.

The principles which I have established serve to explain several observations that Lewis has made upon this subject, and of which I shall now relate the principal.

Ink that is made by simple infusion is of a pale colour, and becomes black only by keeping : but if we wish to have it at once a black ink, it is necessary to imitate the dyers, who boil the astringents in water for a long time, and afterwards add the sulphate of iron : for, 1. By boiling, we dissolve a greater quantity of the astringent principle ; 2. By adding the sulphate of iron to the liquor, while still very warm, we more readily obtain an effect analogous to the slight combustion, that takes place, when the oxygen combines with the astringent principle.

Recent ink, as well as stuffs immediately taken out of the dying vat, assumes always a deeper black by the contact of air ; it appears, that this effect is owing to the oxygen which the galls separate from the iron, not being sufficient for the degree of combustion necessary to produce the black required ; and that this combustion is completed by the oxygen which is attracted from the atmosphere.

Ink, in the formation of which a large proportion of the sulphate of iron has been employed, readily becomes brown by the action of the sun, and of the air, and at last yellow ; because the iron which is not saturated with the astringent principle continues to attract powerfully the oxygen, and by this it loses its black colour,



colour, and assumes one that approaches more and more to a yellow; and, at the same time, the combustion of the astringent principle proceeds rapidly, especially by the influence of light; but the ink is much more durable if the astringent principle exists in a sufficient proportion.

The best, according to Lewis, is composed of three parts of galls and one of the sulphate of iron. He found that characters which had become brown or yellow, recovered their colour in consequence of being moistened by an infusion of galls. Dr Blagden has used the prussiate of alkali with success to recover writings worn out by age, and he found it more advantageous than galls.

Although chemists have considered the astringent as one and the same principle, experience has shown that all astringent substances are not equally fit for producing a beautiful and solid black: it is of consequence to ascertain those which may be employed with success; but it must be observed, that it is very difficult to give precision to comparative experiments made upon this subject, because some substances require much longer boiling than others for the extraction of the astringent principle; and the finer or coarser form under which we subject these substances to boiling, may afford different results; and because the colouring particles have a stronger or weaker disposition to combine with the stuff, according to the proportions of the sulphate of iron that have been employed.

It is necessary also to observe, that the solutions of iron by different acids may produce variations in the results,

results, according to the more or less oxygenated state in which the iron exists, according to the greater or less proportion of this metal, and according to the stronger or weaker action that the different acids, now set at liberty, may exert upon the combination which is formed. Lastly, in the dying of a piece of stuff, the stronger or weaker affinity of the stuff for the colouring particles, may also produce changes in the results.

Lewis has observed, that the decoction of logwood used instead of simple water for the infusion of galls, increases the beauty of the ink without rendering it more pale. Sumach, the bark of the plumb, the pomegranate, the flowers of the pomegranate, the roots of bistort, tormentil, the bark of the oak, do not possess the efficacy of galls. In his experiments on dying, he found that sumach, the bark of the oak, and the saw-dust of the same wood, could only supply the place of galls, by employing them in larger proportions.

M. Beunie has published a great number of interesting experiments \*; his object was, to determine the best method to dye cotton of a fixed black. He tried at first what solution of iron gives the most beautiful black to galled cotton; afterwards he combined different solutions; he tried the solidity of the blacks he produced; he made the same trials with other metals and semi-metals upon galled cotton; he employed a great number of astringents in the same manner, and he subjected to trial cottons which had been prepared in

\* Mémoire sur la Teinture en noir, qui a remporté le prix de la société littéraire de Bruxelles en 1771. Rotterdam, 1777,

in different ways. We shall find, in the section of the second part which treats of dying black, the processes to which these repeated experiments have given rise.

Of twenty-one kinds of astringents compared with galls, the saw-dust of oak, the galls of this country, and the myrobalan citrons, are the only substances that produce a beautiful black, but which is still neither so beautiful nor so solid as that produced by common galls. He found that the saw-dust of oak is preferable to the bark which is employed by the dyers of thread, and he remarks that it is cheaper.

M. M. Lavoisier, Vandermonde, Fourcroy, and myself, have been engaged in making experiments upon different astringents, in order to draw up a report which the academy entrusted to us. The substances upon which we judged it proper to make comparative trials were galls, oak bark, the raspings of oak, taken from the interior part of the wood, the raspings of the inner bark of the oak, logwood and sumach. To determine the proportion of the astringent principle contained in these substances, we took successively two ounces of each, and boiled them for half an hour, in three pounds of water; after the first, we used a second water, which underwent a similar boiling, and we continued these operations until the substances appeared to be exhausted; we mixed the decoctions together that we had successively obtained; we employed a very clear solution of sulphate of iron, in which we knew exactly the proportion of the water and the sulphate; we estimated, at first, the quantity of the astringent principle by the quantity of the

the sulphate that each liquor decomposed, and afterwards by the weight of the black precipitate that was formed. In order to stop at the precise point of saturation, it is necessary to carry on the precipitation very slowly, by pouring in the solution of sulphate towards the end only drop by drop, and by stopping directly, when a new addition of this substance does not increase the intensity of the black colour. When the liquor is too opaque, so that we cannot distinguish the shade of the colour, we dilute a small portion of it with a great quantity of water, and by adding a little of the solution of the sulphate of iron in the end of a glass tube, we shall be able to know if it has reached the point of saturation; if we wish to preserve the precipitate that is formed, it is necessary to dilute the liquor largely with water.

This operation deserves attention, because it affords an easy and accurate method of determining, in the workshops, the proper proportions of astringents and of solutions of iron.

Three drachms 61 grains of galls were necessary to saturate the decoction of 2 ounces of galls; the precipitate collected and dried weighed 7 drachms 24 grains.

The decoction of oak bark is of a deep yellow colour; a very small quantity of sulphate of iron gives it a dirty red colour: a farther addition changes it to a black brown. The quantity of sulphate necessary to saturate the decoction of 2 ounces of this bark was 18 grains; the precipitate, consisting of larger particles, which were more difficult to divide, when collected and dried weighed 22 grains; the liber, or inner



ner bark of the oak, presents nearly the same results.

The decoction of the saw-dust of the heart of the oak requires, for its saturation, 1 drachm and 24 grains; the precipitate was precisely of the same weight; the decoction of the inner bark of the oak affords very little precipitate.

The decoction of sumach assumes a red violet colour, when we add to it a small quantity of the solution of the sulphate of iron. The quantity necessary for its saturation was 2 drachms and 18 grains. An accident prevented us from ascertaining the weight of the precipitate; it resembled perfectly that afforded by galls.

The decoction of logwood receives a sapphire blue colour from the addition of the sulphate of iron. If we exceed the point of saturation, the blue becomes of a dirty greenish colour. The quantity necessary for complete saturation was found to be 1 drachm 48 grains, and the weight of the precipitate was 2 drachms 12 grains. All the precipitates of the oak are formed readily; that of logwood with a little more difficulty, but still with more facility than that of galls.

We afterwards found by trials made upon woollen stuff, that the quantity of astringents necessary to produce a black colour equally deep, on equal weights of the same stuff, are proportional to the quantity of the astringent principle in each substance, which we had ascertained by the foregoing experiments: but the black obtained from the different parts of the oak did not stand boiling nearly so well as that produced by galls.

It does not appear that logwood alone can produce a black so deep as galls, or oak; and, besides, the colour that it produces does not stand boiling so well as the one obtained from galls.

We read in the memoirs of Stockholm, for the year 1763, that the *uva ursi* gathered in Autumn, and dried with care, in order that its leaves may remain green, may be used as a substitute for galls.

The theory which I have given with regard to astringents is far from being complete in all its different parts; but it establishes principles, the application of which may afterwards be made by experiments, that ought to be much more varied and more accurately performed than any that have hitherto been attempted. It will be necessary to confine ourselves to the principal astringents only, because the greater number of vegetables possess more or less of an astringent property, as may be seen from the trials of Bergius\* and M. Durande†.

After having considered the astringent principle in its relations with the solutions of iron, it remains to consider it with regard to the property which it has of combining with vegetable and animal substances, particularly the latter. Silk acquires by galling‡, which consists in macerating a stuff in a decoction of galls, a weight that cannot be taken from it by repeated

\* *Materia medica e regno vegetabili.*

† *Mém. sur les parties astringentes indigenes. Acad. de Dijon*  
1783.

‡ I shall apply the word *galling* to denote the combination of an astringent with a stuff, of whatever nature either of them may be.

peated washings : or, at least, that can only be diminished to a certain degree : after this operation, the stuff, immersed into a solution of iron, is dyed black ; because the astringent principle, by decomposing the sulphate of iron, forms a triple combination with the oxid of the iron and the stuff.

A stuff that has been galled may combine with other colouring particles, in consequence of which their colours will acquire solidity if they have it not of themselves ; so that the astringent communicates its own fixedness to the triple combination, and sometimes to a more compound one that is formed, and commonly the colour becomes deeper by this combination.

By combining with animal substances, the astringent principle secures them from corruption, and tends to contract the texture of their parts ; it is in this that tanning, the basis of the preparation of leather consists.

The prize which the Academy of Sciences has proposed, with regard to this important art, will certainly procure more extensive information, and serve to promote the progress of the art : but I hope the conjectures I have formed will not be altogether useless to those who shall turn their attention to this subject.

An ounce of galls, distilled with a strong heat, affords 3 drachms of carbon ; an ounce of sugar, 2 drachms 12 grains ; an ounce of the colouring particles of thread, 2 drachms 24 grains ; an ounce of plumb-tree well dried, 1 drachm 48 grains ; an ounce of dry walnut-tree, also 1 drachm 48 grains : so that  
galls

galls afford almost double the quantity of carbon that hard and dry wood does. I have elsewhere remarked \*, that when the infusion of galls, and that of sumach, are decomposed by means of the oxygenated muriatic acid, a copious precipitate of carbon is formed, particularly in the former.

From these observations, I consider the superabundance of carbon as the essential characteristic of the astringent principle: the hydrogen, which exists only in a small quantity, has a strong tendency to combine in part with oxygen: from this it happens, that when we allow the infusion of galls to remain in contact with vital air, only a small absorption of vital air takes place, although the colour of the infusion becomes much deeper: for in conformity with the theory I have delivered in the third chapter, and particularly in the *Annales de Chymie*, the carbon, by means of this slight combustion, becomes the prevailing ingredient, and the colour deepens and becomes brown.

A substance which contains a great quantity of carbon, and which can undergo only a slight degree of combustion, should be of a very fixed nature, because carbon does not combine with oxygen in the ordinary temperature of the atmosphere, unless this combination be assisted by other affinities, and because slight changes in the temperature do not produce any in the dimensions of the carbon: on the contrary, substances which contain much hydrogen, and in which the particles of the hydrogen are very much divided, ought to be easily decomposed by the combination of

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\* Ann. de Chym. tom. VI.



the hydrogen with azote, or with oxygen. The separation of their particles ought to be produced by small changes in the temperature, because the hydrogen is dilatable by heat, while the carbonaceous particles are not. It is in this manner, according to the ingenious remark of M. Monge, that a very fusible metal, mixed with a metal that is much less so, renders the latter brittle in a degree of heat, which, by fusing the former, destroys the continuity of the particles of the mixture.

When, therefore, the astringent principle is combined with an animal substance, it communicates to it the properties which it derives from carbon; the animal substance becomes less easily altered by slight changes in the temperature; instead of becoming putrid, it undergoes a slight combustion by the action of air: for, in all likelihood, tanning could not be performed in a vessel closely shut: the effect of this combustion is the contraction of the particles of the subject, and this tends afterwards to preserve it from putrefaction. The preliminary operations of tanning consist chiefly in extracting all the fatty parts which are diffused in the cellular texture of skins, so as to allow the astringent principle, and even the air, to penetrate through them.

When I examine the analysis that has been made of indigo, which may be considered as the least changeable of all known colouring bodies, I observe, that this substance affords by distillation a greater proportion of carbon than galls themselves. I omit in these calculations the carbon which enters into the composition of the thick oil that we principally obtain

tain from indigo, and that which is disengaged under the form of carbonic acid, and of carbonated hydrogenous gas.

It appears to me, that we must also attribute the fixity of the colour of indigo to this superabundance of carbon, and that the different proportion of this principle, is the chief cause of the difference observed in the fixity of colours; but the force of adhesion may also have much influence; for a principle that unites intimately with any substance, ought to form a more lasting combination than another principle which is more feebly disposed to unite with it; but the astringent principle possesses this tendency to combine intimately in a very high degree, particularly with animal substances. I shall explain, by the same principles, the fixity that is communicated to the colouring particles by alumine, and those metallic oxids which are not subject to variations in the quantities of oxygen they contain, such as the oxid of tin.

All colouring substances which can combine with metallic oxids exert upon them an action analogous to that of astringents. Oxids are by this means more or less deprived of their oxygen, according to the force with which they retain it; the strength of the affinity by which the colouring particles tend to combine with them; the proportion in which they meet, and the greater or less disposition the colouring particles have to undergo combustion.

The colouring particles, on their part, undergo a change in their nature proportional to these circumstances; thus the solutions of iron change all colours to a brown, into which the oxid of iron can en-

ter, although it has only a green or yellow colour in the state in which it is kept in solution by acids ; and this effect goes on increasing to a certain point ; but the alteration of the colouring particles may afterwards be carried to a degree at which their colour is destroyed, and their tendency to combination diminished ; the oxid of iron is then brought back to a yellow, by the oxygen which it attracts and retains.

The mutual action of colouring particles, and of metallic oxids, explains the changes that are observed in the solutions of the colouring particles when mixed with metallic solutions. The effect produced is gradual, as I have already observed with regard to yellow wood.

Sometimes the mixture is not disturbed at first ; it loses its transparency by degrees ; precipitation begins ; a deposition is formed ; and its colour becomes deeper and deeper. Light has considerable influence in producing these effects.

## CHAP. VI.

*Recapitulation of the theory delivered in this section.*

**I**T is necessary to distinguish metallic colours from those which belong to vegetable and animal substances.

The colours of metals are modified and changed by oxidation, according to the proportion of oxygen that is combined with them.

Vegetable

Vegetable and animal substances may possess of themselves a particular colour, varying in the different states through which they pass, or they may owe their colours to colouring particles, which are either combined or simply mixed with them. There are particles of this kind, extracted from a variety of substances, which undergo different preparations, in order to serve the purposes of dying.

Colouring particles have chemical properties which distinguish them from all other substances; the affinities they have with acids, alkalies, earths, metallic oxids, oxygen, wool, silk, cotton, and thread, constitute the most important part of these properties.

In proportion to the affinity which the colouring particles have with wool, silk, cotton, and thread, they combine more or less readily, and more or less intimately, with each of these substances; and from this arises a primary difference in the processes we employ occasioned by the nature of the stuff, and that of the colouring substance.

By the affinity that the colouring particles have for alumine, and the metallic oxids, they form with these substances a combination, in which their colour is more or less modified, and becomes more fixed, and less easily affected by external agents than formerly. This combination, being formed of principles which separately possess a disposition to unite with vegetable, and principally with animal substances, retains this property; it forms a triple combination with the stuff, and the colour which has been again modified in consequence of this triple union, acquires a greater de-



gree of fixity, and a greater power of resisting external agents.

The colouring particles frequently have such an affinity for the alumine and metallic oxids, as to separate them from acids which kept them in solution, and form with them a precipitate; but sometimes the affinity of the stuff is necessary to effectuate this separation.

The metallic oxids which combine with the colouring particles not only modify their colours by their own peculiar colour, but also act upon their composition by the oxygen they contain. The change that the colouring particles undergo by this means is similar to that which they suffer from the air, by which all colours are more or less injured.

Of the two principles which form atmospheric air, it is only the vital air, or oxygenous gas, that acts upon the colouring particles; it combines with them, and then weakens their colour and renders it pale: but its action is soon exerted, chiefly upon the hydrogen, which enters into their composition, and with it forms water. This effect must be considered as a true combustion. By it the carbon, which enters into the composition of the colouring particles, becomes prevalent; and the colour passes generally to a yellow, to a fawn, to a brown; or this degradation, by mixing with what remains of the first colour, produces other appearances.

Light promotes the combustion of the colouring particles, which frequently cannot be performed without its assistance; and it is in this way that it contributes to destroy colours. Heat also favours it, but less

less effectually than light, till raised to a certain degree.

It is on a similar combustion that the effects of the nitric, the oxygenated muriatic, and sulphuric acids depend, when they change the colour of the substances upon which they act from a yellow to a black \*.

The effects of combustion may be concealed by the oxygen combining with the colouring particles, without exerting its action in a particular manner upon the hydrogen.

Colours are more or less solid, and more or less fixed, according to the greater or less tendency that the colouring particles have to undergo this combustion, and that in a greater or less degree.

There are some substances which may act as solvents on the colours of stuffs, in consequence of their superior

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\* There are a great number of other natural phenomena, besides those I have already mentioned (*Ann. de Chem. T. VI.*) in which the formation of water appears to me to be undeniable; thus the bitter taste of unripe fruits is probably owing to oxygen feebly combined; but during maturation, the fruit which was hard becomes soft; water is formed; the juice becomes saccharine and copious: but sugar contains a large portion of carbon. When the fruits are too ripe, and suffer the degeneration that is natural to them, their colour indicates the superabundance of carbon. It appears from the experiments of the celebrated Ingenhousz (*Exper. sur les vege, T. II.*) that combustion takes place on the surface of fruits exposed to the sun, to such a degree as to produce carbonic acid.

Dung, either alone or mixed with straw or chaff, is converted into mould by a combustion that is even accompanied with considerable heat, so that the carbon becomes superabundant in the latter. On this depend perhaps many of the phenomena of vegetation.

rior affinity : of this kind are acids, alkalies, and soap; however, a small part of these agents may sometimes be superadded to the stuff, and in that way alter its colour.

Metallic oxids produce in the colouring particles with which they unite a combustion proportional to the quantity of oxygen which can be taken from them by these particles.

The colours that the combinations of the metallic oxids with the colouring particles assume, are then the conjoined effect of the colour belonging to the colouring particles, and of that of the metallic oxid; but it is necessary to consider the colouring particles and the metallic oxids in the state to which the diminution of oxygen reduces the latter, and the diminution of hydrogen the former.

It follows from this, 1. That metallic oxids, to which the oxygen adheres very weakly, are not fit to be employed as intermediate substances to the colouring particles, because they would produce too great a degree of combustion; such are the oxids of silver, gold, and mercury.

2. That oxids which undergo considerable changes in their colour, by parting with a greater or less quantity of oxygen, are also unfit for intermediate substances, especially for clear shades, because they produce changeable colours; such are the oxids of copper, lead, and bismuth.

3. That the oxids which have a strong affinity for their oxygen, and which suffer little change of colour by the loss of a portion of it, are the fittest for this purpose; such in particular is the oxid of tin, that  
readily

readily quits its solvent, that has a strong affinity with the colouring particles, and affords them a very white base, and one proper to give brightness to their shades, without altering them by the mixture of any other colour. The oxid of zinc possesses in part these properties.

To account for the colours resulting from the combination of the colouring particles with the base that a *mordant* affords them, it is likewise necessary, to attend to the proportion in which the colouring particles unite with this base : thus the solution of tin, which forms a very copious precipitate with a solution of colouring particles, and by this shows that the oxid of tin enters in a large proportion into the precipitate, has much greater influence by the whiteness of the base upon the colour of the precipitate than the solution of zinc, or that of alum, which generally form a much less considerable quantity of precipitate. The precipitates produced by these two last substances retain nearly the natural colour of the colouring particles.

It is necessary, therefore, in the action of *mordants*, to distinguish the combinations which may be formed by their means between the colouring particles, the stuff, and the intermediate substance, the proportions of the colouring and intermediate substances, the modifications of colour that may take place from the mixture of the colour of the colouring particles, and of the base to which they are united, and, lastly, the changes that the colouring particles may undergo from the combustion which may be produced by the intermediate substance.

Astringents



Astringents do not owe their distinguishing quality to an acid, or to any other identical principle ; but to the property which they possess, of combining with the oxid of iron, of bringing it back to the state of a black oxid, and of assuming themselves a brown colour from the combustion which they by this means undergo.

Galls, which we ought to consider as the representatives of the class of astringents, readily undergo a slight combustion, that gives them a deep brown colour ; but this combustion, which requires only a small quantity of oxygen, is speedily stopt without affecting their properties.

These substances owe their durability to the great quantity of carbon they contain ; and as they possess the property of combining with some vegetable substances, with many colouring particles, and especially with animal matters, they serve as an intermediate substance between them, and communicate to them their own durability.

## SECTION

## SECTION SECOND.

## ON THE OPERATIONS OF DYING IN GENERAL.

## CHAP. I.

*Of the distinguishing characters of wool, silk, cotton, and flax, and of the operations by which they are prepared for dying.*

## ARTICLE I.

*Observations on the difference between animal and vegetable substances.*

I DARE not flatter myself with the hope of explaining many of the properties which depend on the composition of organized matter ; but the knowledge we have already acquired, with regard to the composition of vegetable and animal substances, will enable us, in some degree, to discover the cause of the different tendencies that wool, silk, cotton, and flax have to unite with the colouring particles, or with the bases which *mordants* afford.

Wool and silk belong to the class of animal ; cotton, flax, and hemp, to that of vegetable substances.

The principal distinguishing character in the composition of vegetable and animal substances is, 1. Animal substances contain a great quantity of a peculiar principle, *azote*, which in the elastic state forms what is called *phlogisticated gas*, or *phlogisticated air*. This is found only in very small quantity in vegetables :

2. Animal substances contain a greater quantity of hydrogen or the base of inflammable gas.

The differences that are observed in the distillation of animal and vegetable substances, arise from these two causes: the former afford a great quantity of ammoniac, which is a compound of azote and hydrogen; the latter afford only a small quantity, and in general give rather an acid. The former afford a great quantity of oil, the prevailing ingredient of which is hydrogen: this oil, at a temperature somewhat high is strongly disposed to separate, and to be evaporated; the latter sometimes do not afford the smallest quantity. In consequence of this composition, animal substances produce at the commencement of their combustion, a very bright flame, but this is quickly suffocated by the carbon that is formed, and which possesses peculiar characters. Their combustion is accompanied by a penetrating odour, owing to the ammoniac and oil that are formed, and escape the inflammation; they are subject to putrefaction, during which, ammoniac is evolved, as in distillation, by the more intimate union of the azote and hydrogen; while, on the contrary, vegetables undergo only a spirituous or an acid fermentation. In this place, I merely allude to opinions that I have explained at full length in some other memoirs.

The particles of animal substances, containing a number of principles disposed to assume the elastic state, adhere less strongly among themselves, than those of vegetables, and are more disposed to combine with other substances.

On

On this account, they are more liable to be destroyed by different agents, and more disposed to combine with the colouring particles.

Thus the fixed alkalies, either pure or caustic, destroy animal substances, because they combine with them; in consequence of which, they become saturated and lose their causticity\*.

From this action of alkalies on animal substances, it happens, that they cannot bear the action of leys, and that alkalies ought to be employed with great caution in the processes of dying, while, on the contrary, no dread can be entertained respecting the use of alkalies for vegetable substances.

The nitric and sulphuric acids have also a strong action upon animal substances. The former decomposes them, disengages the azote, separates the fat, and forms the carbonic and oxalic acids, with a part of the hydrogen, and a part of the carbon; the latter disengages inflammable gas, probably also azotic gas, and reduces the other principles to a carbonaceous state.

Silk appears to approach in some degree to vegetable substances, by a weaker tendency to unite with the colouring particles, and by a greater resistance to the action of acids and alkalies, which may arise either from the same principle being more intimately combined in it than in wool, or more probably from the smaller quantity of azote and hydrogen it contains; but although the action that alkalies and acids exert

\* Mem. de l'Acad. 1783.



exert upon silk, be not so strong as upon wool, it is nevertheless necessary to use them with great caution, because the brightness of the colour we wish for in silk, appears to depend upon the smoothness of its surface, which must not be injured.

Cotton resists the action of acids better than flax or hemp, and it is only with difficulty that we are able to destroy it by the nitric acid.

## ARTICLE II.

### *Of Wool.*

The principal differences of wool consist in the length and fineness of its filaments. Wool which has very fine filaments is reserved for the best superfine cloth. The finest is brought from Spain; M. d'Aubenton has proved that we can obtain wool in France, not inferior to that from Spain, by making a careful selection of rams, and by confining the sheep in parks through the whole year. As the sight alone is apt to deceive us with regard to the fineness of wool, and as it is of consequence to manufacturers to know it with accuracy, he has given a method of determining it with the necessary precision, by using a micrometer, in order to compare with the microscope, the fineness of the wools we wish to examine, with that which we choose as a term of comparison\*.

Although long wool be not so fine as Spanish wool, and therefore cannot be employed for superfine cloths,  
it

\* Mem. de l'acad. 1779. Instructions pour les bergers & pour les propriétaires de troupeaux.

it is, however, very useful for the woolen stuffs known by the name of English cloths; and as the sheep which afford it have by far the strongest fleeces, the advantages obtained are not inferior to those from the fine wool; besides, the cloths that are formed of their wool are cheaper, and have a more extensive sale; the English owe the prosperity of their commerce in part to the abundance of this wool. But the breed of sheep that afford the one or the other kind of wool, depends in some measure on the nature of the pasturage, a circumstance that ought to make us careful in the choice of it.

It is of so great consequence to our manufactures to multiply our flocks, and to improve our wool, that no opportunity of calling the attention of the public to this object should be lost.

Wool is naturally covered with a kind of grease that is called the *sweat*. This coating preserves it from moths, so that wool is only scoured when it is to be dyed or spun.

To scour wool, it is put for a quarter of an hour into a copper, containing a sufficient quantity of water mixed with a fourth part of putrid urine heated till the hand can just bear it, and stirred from time to time with a stick; it is then taken out and drained; after this it is put into a large basket, placed in running water, and stirred till the grease is entirely washed out, and renders the water no longer milky; it is then taken out again and drained. It sometimes loses during this operation more than a fifth of its weight. It is of importance that the scouring be performed with care,

care, because by means of it the wool is more disposed to take on the dye.

The ammoniac, or the volatile alkali, which is formed in putrid urine, combines with the grease, and forms a soap with it, by which it is rendered soluble in water.

Wool is dyed in the fleece, or without being spun, especially when it is intended to be formed into cloths of mixt colours; or it may be dyed after it is spun, and it is then chiefly intended for tapestry; but it is most commonly dyed in the form of cloth.

When wool is dyed in the fleece, its separated filaments absorb a greater quantity of colouring particles than when it is spun; for the same reason, spun wool takes up more than cloth; but cloths vary much in this respect, according to their degree of fineness, and their looser or closer texture; besides, the difference of their dimensions, the changeable qualities of the ingredients used in dying, and the different circumstances of operations, prevent us from trusting to the precise quantities recommended in the processes that are described.

This consideration ought to be extended to all dyes.

For the greater part of colours wool requires to be boiled in a vat with saline substances, principally with alum and tartar; this is what we call *bouillon*, and which we will have an opportunity to describe in various processes; but there are dyes for which wool does not require these preparations; it is then necessary to wet it with lukewarm water, and afterwards to express it or allow it to drain. This precaution is generally necessary with all those substances we mean to dye, in order that

that the colour may be more easily introduced, and more equally distributed.

M. Monge has explained the process of felt-making, and the effects of fulling, from the external conformation of the wool and hair of animals. He has made a number of curious observations on this subject, the principal of which I shall relate in his own words :

“ We can discover nothing peculiar in the surface  
“ of fibres of the wool and hair of animals ; how-  
“ ever, the surfaces of these objects are not smooth,  
“ they must be formed, either of plates laid upon one  
“ another from the root to the point, almost in the same  
“ manner as the scales of fishes rest upon one another  
“ from the head to the tail ; or, perhaps, rather of  
“ zones placed above one another, as is observed in  
“ horns.

“ If we take a hair by the root in one hand, and  
“ make it slide between two fingers of the other, from  
“ the root towards the point, we feel almost no fric-  
“ tion or resistance, and we hear no noise ; but if, in  
“ laying hold of it by the point, we make it pass in  
“ the same manner between the fingers of the other  
“ hand, from the point towards the root, we feel a resist-  
“ ance that did not occur in the former case ; a tremu-  
“ lous motion is produced perceptible to the touch,  
“ and also manifested by a sensible noise.

“ We have already seen, that the texture of the  
“ surface of a hair is not the same from the root to the  
“ point as from the point towards the root ; and that  
“ a hair, when it is pressed between the fingers,  
“ finds greater resistance in sliding, and taking a pro-  
“ gressive motion towards the point, than in taking the



“ same motion towards the root; but as this texture is the principal object of the present memoir, it may be necessary to prove it still farther by some other observations.

“ If, after having laid hold of a hair between the thumb and forefinger, we make these slide alternately upon one another in the direction of the length of the hair, the hair takes a progressive motion in that direction, and its motion is always directed towards the root. This effect is not connected, either with the nature or texture of the skin of the fingers; for if we turn the hair so that the point may be in the place of the root, the motion takes place in a contrary direction; that is to say, the motion is always directed towards the root.

“ These remarks, to which M. Monge has added many others, are all made upon a human hair taken as an example; but they are equally true when applied to horses hair, to the fibres of wool, and, in general, to the hairs of all animals. The surface of all these objects is formed of rigid plates, placed above one another in the form of tiles, from the root to the point, which allow progressive motion towards the root, and oppose a similar motion towards the point.

“ It is this conformation which is the principal cause of the aptness for felt-making, that the hairs of all animals possess.

“ In short, the hatter, by striking the flocks of wool with the cord of his bow, detaches and separates each fibre in particular; these fibres fall back upon one another in every direction on the table, where they form

“ form a layer of a certain thickness; the workman  
 “ then covers them with a piece of cloth, which he  
 “ presses with open hands, moving the hands in dif-  
 “ ferent directions. The pressure brings the fibres of  
 “ the wool together, and increases the points of con-  
 “ tact. The agitation gives to each of them a pro-  
 “ gressive motion towards the root; by means of this  
 “ motion the fibres are interwoven with one another,  
 “ and the plates of each fibre, by catching those of  
 “ other fibres that lie in a contrary direction, keep  
 “ the whole in the compact texture which the pressure  
 “ has made it assume. In proportion as the texture be-  
 “ comes compact, the pressure of the hands ought to  
 “ be increased, both to render it more compact, as  
 “ well as to support the progressive motion of the fi-  
 “ bres and their interlacement, which find then a  
 “ greater resistance; but in the whole of this opera-  
 “ tion the fibres of the wool lay hold only of one  
 “ another, and not of the cloth, the fibres of which,  
 “ as has been already observed, are smooth, and do  
 “ not afford the same opportunity.

“ The structure of the surface of the fibres of wool,  
 “ and the hairs of animals, does not alone constitute  
 “ their aptitude for felt-making; it is not sufficient  
 “ that each fibre can assume a progressive motion to-  
 “ wards the root, nor that the inclined plates, by lay-  
 “ ing hold of one another, preserve the texture in the  
 “ state produced by pressure: it is also necessary that  
 “ the fibres be not straight like needles; by means of  
 “ agitation each of them would continue its progres-  
 “ sive motion without changing its direction, and the  
 “ effect of the operation would be the separation of

“ the whole from the centre, without producing any  
“ interlacement. It is necessary then, that each fibre  
“ be curled, that the extremity which is next the  
“ root be disposed to change its direction perpetually,  
“ to warp itself around new fibres, and to return up-  
“ on itself, if determined by any change in the position  
“ of the other parts of its body. It is because the  
“ wool is naturally formed in this manner that it is  
“ so proper for felt-making, and that it can be em-  
“ ployed without any necessity of making it under-  
“ go any previous preparation.

“ But the hairs of the rabbit, the hare, and the  
“ beaver, are naturally straight ; they cannot be em-  
“ ployed for felt-making, without having under-  
“ gone a preliminary operation, which consists in rub-  
“ bing them, before taking them off the skin, with a  
“ brush impregnated with a solution of mercury in  
“ the nitric acid. This solution, by acting only upon  
“ one side of the hairs, changes their direction from  
“ a straight line, and gives to them the aptness to  
“ felt-making which wool naturally possesses.

“ The operation of fulling woollen stuffs has so  
“ great a relation with felt-making, that I believe  
“ it will be necessary here to enter into some details  
“ on the subject.

“ The asperities on the surface of the fibres of wool,  
“ and their tendency to take a progressive motion to-  
“ wards the root, is an obstacle to the spinning of  
“ wool and the making of stuffs. In order to spin  
“ wool, it is necessary to tease it, and afterwards to  
“ cover all the fibres with a layer of oil, which by  
“ filling

“ filling the cavities renders the asperities less percep-  
 “ tible, in the same manner as we put a layer of oil  
 “ on a smooth file to render it still smoother. When  
 “ the piece of stuff is made, it is necessary to cleanse it  
 “ from this oil, which gives it a disagreeable smell, and  
 “ might prevent it from taking on the dye we wish to  
 “ give it : for this purpose, they are carried to the ful-  
 “ ling machine, where they are beat with mallets  
 “ in a trough full of water mixed with a quantity  
 “ of clay. The clay combines with the oil, and ren-  
 “ ders it soluble in water ; the whole is made to pass  
 “ through fresh water brought to it by the machine  
 “ itself, and after a certain time the stuff is scoured.

“ But scouring is not the only object of fulling ;  
 “ the alternate pressure that the mallets exert upon  
 “ the piece of stuff, especially when the scouring is far  
 “ advanced, produces an effect analogous to that occa-  
 “ sioned by the hands of the hatter ; the fibres of wool,  
 “ which compose one of the threads of the warp or  
 “ woof, take a progressive motion, and insinuate them-  
 “ selves into the contiguous threads, then into those  
 “ which follow ; and, in a short time, all the threads of  
 “ the warp, as well as of the woof, are felted together.  
 “ The stuff, after having undergone a contraction in all  
 “ its dimensions, partakes both of the nature of a web,  
 “ and that of a felt. We can cut it without its separating  
 “ into threads, and it is not necessary to hem the dif-  
 “ ferent pieces of which a garment is formed. If it is  
 “ an ordinary knitting of wool, the stitch is no longer  
 “ disposed to run when it happens to break : in short,  
 “ the threads of the warp and woof being neither so dis-



“ tinct nor separated in so easy a manner, the stuff be-  
 “ comes thicker, and forms warmer cloathing.”

### ARTICLE III.

#### *Of Silk.*

Silk is naturally varnished by a kind of substance which we consider as a gum, and to which it owes its stiffness and elasticity. That which is most common in our country, contains, besides this, a yellow colouring matter.

The greater number of uses for which silk is intended, require not only that it be deprived of its colouring matter, but also of its gum. We obtain both purposes by means of soap, and we give the name of dressing (*decrusage*,) to the operation by which we give to silk its whiteness and its flexibility.

The dressing should not be so complete for silks that are to be dyed as for those that are to be made white; and it even ought to differ according to the colour which the silks are to receive. This difference consists chiefly in the proportion of soap that is employed; thus for ordinary colours we boil the silk for three or four hours, in a solution of twenty pounds of soap to the hundred weight of silk, taking care to fill the copper from time to time with water, so as to have it always in sufficient quantity. We increase the quantity of soap for silks that are to be dyed blue, and especially for those that are to be dyed of a poppy or cherry colour, &c. because a whiter base is required for these than for less delicate colours.

In treating of each particular colour, I shall mention the quantity of soap proper for the silk that is to receive it.

When silk is to be used white, it is made to undergo three operations ; the first is called Ungumming : it consists in keeping hanks of silk in a solution of thirty pounds of soap to the hundred weight of silk ; this solution should be made very warm, but not so as to boil. When that part of the hank which is in the liquor is completely deprived of its gum, which is known from its whiteness and flexibility, we turn the hanks upon the rods, in order to make the part that had not been immersed undergo the same operation ; and we take the hanks out of the vat, wringing them on pegs in proportion as the ungumming is performed.

The second operation is called Boiling ; the silks are shut up in bags of coarse cloth, from twenty-five to thirty pounds of silk in each bag, which is termed a pocket : a soap vat is prepared, similar to the first, only diminishing the quantity of soap, and it is made to boil for an hour and an half, taking care to move the bags one over another, to prevent those at the bottom of the copper from undergoing too great a degree of heat.

The third operation is called Whitening : this operation is chiefly intended to give a slight shade to silk, which renders the white more agreeable, and by means of which it obtains different names. Thus we make a distinction between china white, silver white, azure white, and thread or milk white. A solution of soap is made, so that by beating it with a stick, a

froth is produced, that enables us to judge whether it be of the proper strength; and for china white, which ought to have a reddish hue, we add a little arnotto, and keep the silk there till it acquires the shade desired. We give to other whites a tinge more or less blue, by means of azure added to the solution of soap; but we had previously put in some of it in the boiling.

To prepare azure, we take fine indigo, and after having washed it two or three times in water moderately warm, we pound it in a mortar, and pour boiling water upon it: we allow it to settle, and we use the liquor which retains only the most subtile parts: it is this we call Azure. We can substitute for it a small quantity of the liquor of a new indigo vat.

At Lyons, where they produce a more shining white than at Paris, they use no soap for the third operation; but after the second, they wash the silks, sulphur them, and add the azure in river water. In this method, it is of consequence to use water that is very clear.

When silks are smooth, and have taken on the shade we desire, they are wrung and dried.

The white obtained by the means we have described is not sufficiently bright for silks intended for white stuffs; but it is also necessary to expose them to the vapour of sulphur; this operation is described under the article SULPHUR.

As soap appears to injure the lustre of silk, the academy of Lyons in the year 1761 proposed, as the subject for a prize, to discover a method of dressing silks without soap. The prize was adjudged to M. Rigaut  
de

de St Quentin, who, instead of soap, proposed to employ a solution of salt of soda, or carbonate of soda, diluted in a quantity of water sufficient to prevent it from injuring the silk: but this method must have been found inconvenient, since it is not at all employed, although it be well known, and easily practised.

M. l'Abbé Collomb \* has published a number of observations on the dressing of silk, by means of water alone, which merit particular attention. Having perceived that a skain of yellow silk, which he boiled for about three hours in common water, had lost almost an eighth of its weight, he repeated the boiling twice, and in this way reduced the weight almost a fourth.

Silk which has suffered this loss of weight preserves however a yellow colour, or rather the colour of chamoy leather, which prevents it from being used for stuffs that are to remain white, or to take on colours, the beauty of which depends on the whiteness of the base to which they are applied: but it assumes colours very well which its own tinge cannot injure; thus the black that it takes on is preferable to that of silk dressed with soap.

After this operation the silk remains very strong and tough; threads of it, compared with similar threads dressed with soap, are able to sustain weights that break the latter.

It required eight hours boiling to dissolve all the varnish of the silk, and by this it lost a little more than a fourth

\* Observations sur la dissolution du vernis de la soie. Journ. de Phys. Acut 1785.



fourth part of its weight; but the boiling should be continued longer when the mercury in the barometer is low, because the greater the weight of the atmosphere, the higher is the degree of heat that the water assumes in boiling.

This consideration led M. Collomb to try the boiling of silk in Papin's digester, and indeed it required only an hour and a quarter to produce a complete solution of the varnish, although the degree of heat was inferior to that which ought to produce the effects observed by philosophers in this kind of concentrated boiling.

I have seen a pattern piece of silk dressed by M. Collomb; it appeared to me to possess the qualities mentioned by that author, but it was less flexible and soft than silk dressed with soap.

M. le Camus, a learned naturalist of the Academy at Lyons, sent me a small quantity of the substance that is separated from silk by means of water in the operation of M. Collomb; this substance was black, brittle, and shining in its fractures; it afforded by distillation the products of animal substances; it dissolved very readily in hot water, and left very little residuum upon the filter; the solution, which was clear and of a greenish yellow colour, was not sensibly altered by acids or by alkalies.

The solution of alum produced a dirty white precipitate; that of the sulphate of copper a black brown precipitate; that of the sulphate of iron a brown precipitate; the nitro-muriatic solution of tin a white precipitate; the acetite of lead a brown precipitate.

All these precipitates were scanty, and more or less viscid,

viscid. The infusion of galls and that of sumach produced a white precipitate.

Alcohol did not dissolve this substance, even by boiling, but only a yellow colouring matter. This solution afforded by evaporation a residuum in scales of an amber colour. I mixed some drops of the muriatic acid with nearly two ounces of alcohol that I had boiled, upon twenty grains of the gum of silk, a complete solution was produced; but this substance in cooling assumed the form of a jelly.

The substance that we separate from the silk in dressing is therefore of an animal nature; it is for this reason that the soapy waters employed in the dressing, putrify quickly; when it is no longer retained by its affinity with the silk it dissolves readily in water, but not in alcohol. Although it be not of a vegetable nature, we see the term Gum may be applied to it with great propriety. The yellow colouring part is soluble in alcohol. When this part is separated, the gum becomes brown: it would appear that this colour is produced by the heat it undergoes in boiling, since, when we separate only the yellow colouring part, according to the process of M. Baumé, of which we shall afterwards speak, the silk remains white.

In the process of M. Collomb the gum is also separated, and carries along with it only a part of the yellow colouring particles: but in the dressing with soap, both the gum and yellow colouring particles are separated from the silk.

I boiled yellow silk in a retort, where the vapours being more closely confined than in the open air, ought to produce a degree of heat superior to that of boiling  
in

in the open air: after four hours boiling, the silk had lost nearly a fourth part of its weight, but it preserved its colour almost entire. I boiled, in the same manner, a pattern in water impregnated with marine salt; it became whiter, but lost less of its weight, although the degree of heat was certainly increased by the resistance which the salt made to the evaporation: a part of the marine salt perhaps combined with the silk. Were we to try other salts, we might probably find some which, without injuring the silk, would produce a more ready solution of the gum and colouring part.

When silk is intended to be formed into blond lace and gauzes, it ought to preserve the stiffness and elasticity which are natural to it: the greater part of that produced in our climate has a yellow colour, and it is the white silk from China that is chiefly used for these purposes; but as it is obtained at a price which does not permit our manufactures to support a rivalry with the English, through whose hands it comes to us, especially as they retain the finest for their own manufactures, we have endeavoured to discover a method of depriving yellow silk of its colouring part without affecting its gum, and consequently without depriving it of its elasticity.

M. Baumé has resolved this interesting problem; but he has kept his process secret: some artists, to whom he had communicated it, or directed by some hints, have succeeded in performing this process: however, it appears to be subject to accidents, which increase the expence by the loss they occasion; so that it has not hitherto been generally employed, notwithstanding the advantages that it holds out to our manufactures,

tures. We shall point out what has transpired to the public respecting this process.

A small quantity of the muriatic acid is mixed with alcohol, and the silk plunged into it. It is necessary that the muriatic acid be pure, and do not contain any nitric acid, because this last would give the silk a yellow tinge. It appears that the most difficult part of the process is to produce a white that is equal, especially when we operate upon large quantities. It appears also, that we find great difficulty in drying white silk without its becoming wrinkled; for this reason it is proper to keep it extended while drying: the process would be too expensive, if we did not obtain the alcohol that is loaded with the colouring part, and make it serve for subsequent operations. It is necessary, therefore, to distill it with a gentle heat, in an earthen or glass vessel.

It appears from the above-mentioned experiments, that the muriatic acid serves in this process to soften the gum, so as to enable the alcohol to dissolve the colouring part that is combined with it.

Aluming ought to be considered as one of the general operations of dying upon silk, because without alum, the greater part of the colours we apply to silk would neither possess beauty nor solidity.

To perform this process, we put into a cask or tub about forty or fifty buckets of water, with forty or fifty pounds of Roman alum, which had previously been dissolved in a copper full of water, sufficiently warm; stirring carefully the mixture, in order to prevent the crystallization of the alum.

After



After having washed the silk by beetling it, and even by wringing it upon the pegs to extract the soap it may have retained, we plunge it into the alum vat, where it is allowed to remain nine hours; after which we wring it with the hand over the tub, and carry it to the river to wash it.

We can make a hundred and fifty pounds of silk pass through a vat like the preceding, without any necessity for adding any more alum; but when we perceive that the vat begins to weaken, which a little experience enables us to do by the taste, we dissolve twenty to twenty-five pounds of alum, which is put into the vat as formerly, and we continue to renew the vat in this manner, till it begins to emit a bad smell. We then endeavour to exhaust it by passing the silks through it which are intended for dark colours, such as browns, marones, &c. and we throw it away in order to make a new solution.

Silks are always alumed in the cold, for when they are alumed in a warm vat they are apt to lose a part of their lustre.

#### ARTICLE IV.

##### *Of Cotton.*

Cotton is the down, or soft hair, that is contained in the *seed-pod* of a tree or shrub which grows in warm countries. This down is separated from the seeds by means of a kind of mill which it covers.

Climate has a great influence upon the qualities of cotton, and the different kinds of the cotton tree seem to agree

agree well with heat\*. But a great variety of cotton trees are to be found in the islands of America; and it appears from what M. Bennet† has stated, that the colonies have hitherto neglected to make a selection of those which would be the most profitable, and in consequence of this, they have lost a great part of the advantages they might have obtained from this valuable production.

The principal differences of cotton consist in the length of its filaments, their fineness, their solidity, and colour.

The colour of cotton varies from a deep yellow to a white; that of Siam and Bengal has the deepest colour, and it is often formed into stuffs which preserve its natural colours. The most beautiful kinds are not the whitest, but it is necessary to whiten them by processes similar to those by which we whiten thread, but fewer and less tedious operations are required for cotton than for thread. Instead of these operations, we may employ the oxygenated muriatic acid. Besides saving time, we give it a more beautiful white than by the ordinary bleaching, and from the observations of M. Dècroisille, the stuff appears more disposed to take on the beautiful colours of dying. I have bleached with success the yellow cottons of St Domingo, the ugly and tenacious colour of which renders it useless in commerce.

In

\* Essai sur les caractères qui distinguent les cotons des diverses parties du monde, &c; par M. Quatremere Disjonnal.

† Transactions of the society instituted at London for the encouragement of arts, manufactures, and commerce, vol. 1.

In order to dispose cotton thread to receive the dye, it is made to undergo an operation called *dressiug*. Some boil it in four water, but most frequently an alkaline ley is employed; the cotton is boiled in this ley for two hours, after which it is wrung dry; it is then washed in the river till it renders the water no longer muddy, and is afterwards dried.

The cotton cloths intended for printing are steeped for some time in water, impregnated with about a fiftieth or more of the sulphuric acid; after this, we wash it carefully in running water, and dry it. I have observed that the acid used in this operation dissolves the calcareous earth, and the iron, which may alter the colours of the cloth.

We may consider aluming and galling as general operations in the dying of cotton and of thread, which ought to be employed for the greater number of colours.

Aluming ought to be performed in the proportion of four ounces of alum to each pound of the stuff; the alum is to be dissolved with the precautions pointed out in the preceding article: to this a solution of soda is added, which may be estimated at a sixteenth part of soda to one of alum; some add a small quantity of tartar and arsenic. The thread is well impregnated with this solution, by working it pound by pound; after which, the remainder of the vat is poured upon thread heaped together in a vessel, and it is allowed to remain there twenty-four hours: after the alluming, it is soaked in running water an hour and a half, or two hours, and then washed. I have found  
that

that cotton acquires about a fortieth of its weight during this operation.

Galling is performed with different proportions of galls, or other astringents, according to the qualities of the astringents, and according to the effects we wish to obtain.

We boil for two hours, powdered galls, in a quantity of water, that should be proportioned to the quantity of thread that is to be galled; after this the vat is allowed to cool till we are able to bear the hand in it; we divide it into parts as equal as possible, in order that we may be able to work it pound by pound; and, as in aluming, we pour the remainder upon the whole cotton put together. We allow it to remain twenty-four hours, especially when it is intended for a madder colour, or for black; but for other colours, twelve or fifteen are sufficient; after this, we wring and dry it.

When stuffs already coloured, are to be galled; it is necessary to perform it in the cold, in order that we may not alter the colours. I have found that cotton which has been alumed acquired a more considerable weight in galling, than that which has not been alumed; although only a small quantity of the alumine is fixed upon the cotton, it communicates to it the property of combing in a greater proportion with the astringent principle, and even with the colouring particles.



## ARTICLE V.

*Of Flax.*

As flax and hemp exhibit the same properties with regard to dying, we have seldom judged it necessary to distinguish them in this work.

If cotton is an important object of industry, flax and hemp deserve particular attention both as a national production, and as the most extensive source of labour for the poor. It is a manufacture which is to be found in every part of the country, which admits of subdivision from the fabrication of cordage to that of cambrics, which collects rural families together in the intervals from other labours, and affords them in some measure the sweets of society, which presents an opportunity of habituating infancy to labour, and of acquiring something to render old age comfortable.

At a time when we are everywhere employed in draining marshes, and when the number of small possessions must every day increase, it is a circumstance meriting attention, that the soil fittest for the culture of hemp is that of marshes from which the waters have been drained, and that this production is peculiarly adapted for the employment of small cultivators \*.

Flax ought to undergo several preparations before it is fit to receive the dye. The first is steeping ; by  
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\* Instruction familiere sur la culture & le toui du chanvre a l'usage des gens de la campagne ; par M. de Pertuis.

this the bark, which is afterwards to serve for spinning, is disposed to separate. The steeping is an operation of so great importance, both with regard to its influence upon the quantity and quality of the product, and the deleterious qualities it may communicate to the air, that it may not be improper to give an idea of the principles on which it may be conducted.

It appears that, in steeping, a glutinous liquor that holds the green colouring part of the plant in solution, and which unites the cortical with the ligneous part, undergoes a degree of putrefaction greater or less according to the method we employ ; for as M. Rosier has observed \*, carbonic acid and inflammable gas are disengaged. This substance appears to resemble greatly the glutinous part which is dissolved in the juice expressed from green plants, which separates from the colouring particles when it is made to undergo a heat approaching to boiling, which putrifies and affords ammoniac by distillation.

Although this substance be held in solution in the juice expressed from plants, it appears, however, that water alone cannot separate it from the cortical part ; but it is on this account that hemp that has been steeped in a rapid stream is deficient in flexibility and softness.

If the steeping is performed in stagnant and corrupted water, the hemp acquires a brown colour ; but be-

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\*-Eti sur la culture & le rouissage du chanvre ; par M. l'Abbé Rosier.

sides this, it loses its solidity, and exhales vapours which produce fatal disorders.

It appears then, that the steeping is most advantageously performed in pools planted at the sides of rivers, so that the water may be easily renewed to prevent the putrefaction from being hurtful to the hemp or injurious to health, and yet not sufficient to prevent the degree necessary to render the gelatinous substance soluble in water.

M. Rosier found that the steeping would be performed when the hemp is covered with a layer of earth, and he advises that method; M. Prozet\* has proposed to dissolve a small quantity of caustic alkali in the water in which it is performed, to increase its solvent power and prevent putrefaction; but it appears from the experiments of Dr Home that the alkali retards the operation of steeping and renders the flax brittle†.

While flax is steeping and during the drying which ought to precede and follow it, the green colouring particles undergo a change similar to that observed in the green substance of plants which are exposed to the action of the air and of light; the colour changes to a yellow, to a fawn, and even to a brown, in consequence of the combustion which I explained in the first section. A great part is then soluble in alkalies without requiring to be any further oxygenated; so that by *treating* it with an alkaline solution we can separate from it a considerable portion of its colouring particles,

\* Mém. sur le rouissage du chanvre.

† Essai sur le blanchiment des toiles, p. 270.

particles, which remain perhaps combined with a part of the gluten. It is upon the solution of these colouring particles that the process published by the prince of St Sever for obtaining fine lint from hemp is founded. He orders the hemp to be lixiviated with a solution of two parts of soda to one of lime, afterwards to impregnate it with soap to keep it in digestion to wash it well, and afterwards to comb it.

I have attempted to bleach lint thoroughly by the method I employ for thread; but although its fibres should lose very little of their solidity by this process, they acquire however a greater disposition to separate, and they become more difficult to spin, and form a thread much less solid.

I have made a number of comparative experiments upon lint, prepared by a method similar to that of the Prince de S. Sever, and lint of the same kind treated in the common manner. The first method, afforded a greater proportion of tow, and the thread obtained by it was not finer than by the second, after the latter had been lixiviated; but the former was less solid: however, there is an advantage which deserves attention, that in the dressing, the lint treated in the former method was free of that powder which is so dangerous to the workmen.

The beauty that we produce in lint, by the preliminary lixiviations, does not seem to possess the advantages that its beautiful appearance gives us reason to expect, since we only dissolve that portion of the colouring substance which would be carried away by the first lixiviations with which we begin the bleaching



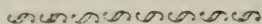
ing. The great degree of fineness we give it, is probably obtained at the expence of the length and solidity of its filaments.

A clergyman of the department of the Somme has rendered his ministry respectable by employing himself with an object in which the real prosperity of the people is so much interested. M. Brale has established near Amiens a kind of public school, where he examines and endeavours to discover the best method for the culture of hemp, for steeping it and for preparing the lint. His process is not attended with the inconvenience I met with in the lixiviation of the lint; he steeps the hemp as soon as it is taken from the earth: After steeping he separates the bark by a particular manipulation and the dipping it in a solution of black soap; he washes it with great care before drying; the colouring part, which is soluble only in alkalies, may still be dissolved and carried away by the water assisted by a little soap; the lint is then much whiter; it divides more readily without doing so too much; and we have the lixiviations which ought to precede the bleaching.

Ordinary thread and cloth that is woven contain a colouring substance which may be separated by simple lixivations; but there is a portion of this substance that is truly combined with the vegetable fibres and which can only be separated by decomposing it by the [combustion it undergoes in combining with oxygen, as I have explained in the third chapter of the first section. Thread loses by the operation of bleaching from a fourth to a third part of its weight.

In

In order to dispose thread to take on the dye it is made to undergo the operations of dressing, aluming, and galling, described under the article *cotton*.

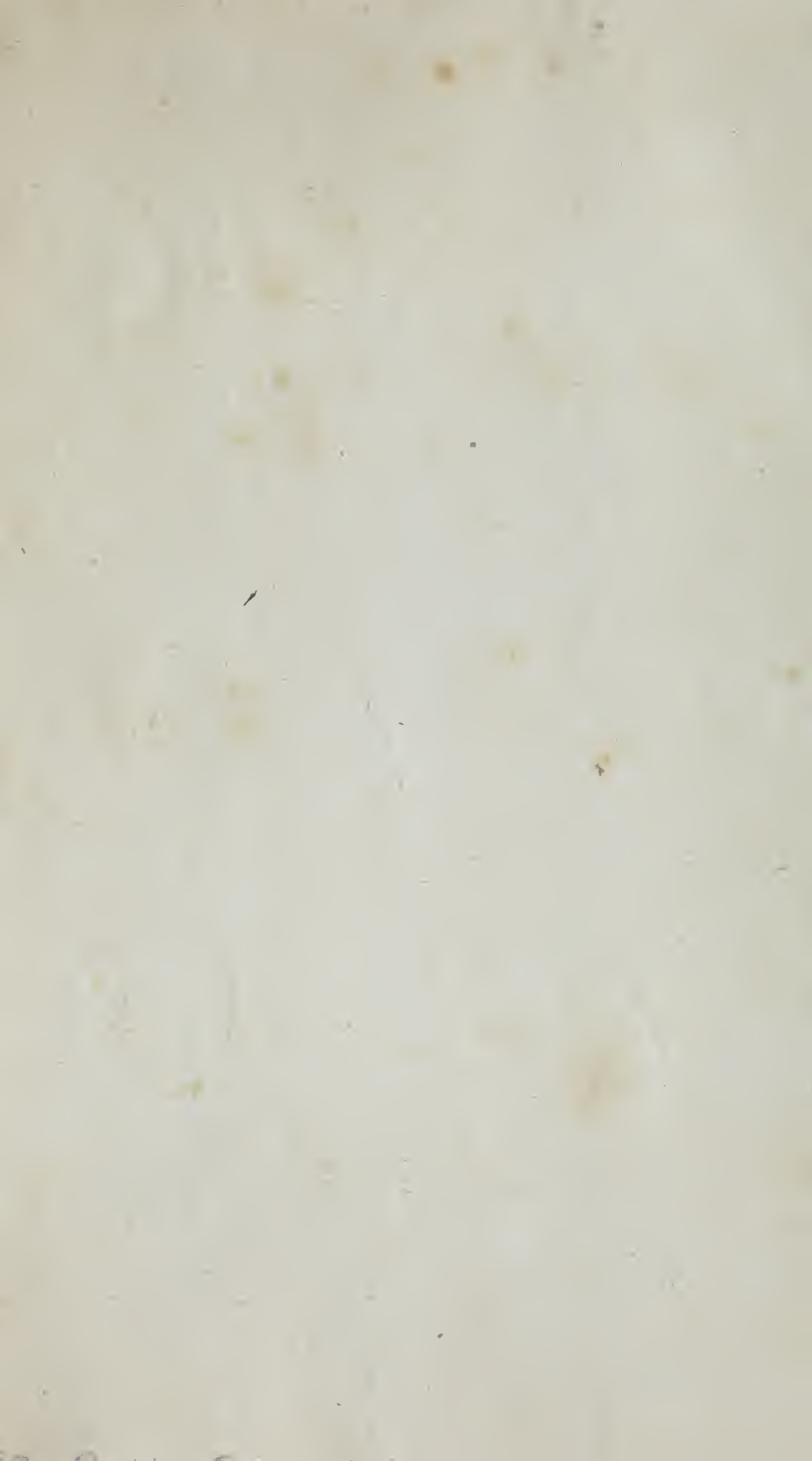


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